AD-A035 944 ARMY MISSILE RESEARCH DEVELOPMENT AND ENGINEERING LAB--ETC F/G 21/8.2
STINGER LAUNCH AND FLIGHT MOTOR CASE EVALUATION.(U)
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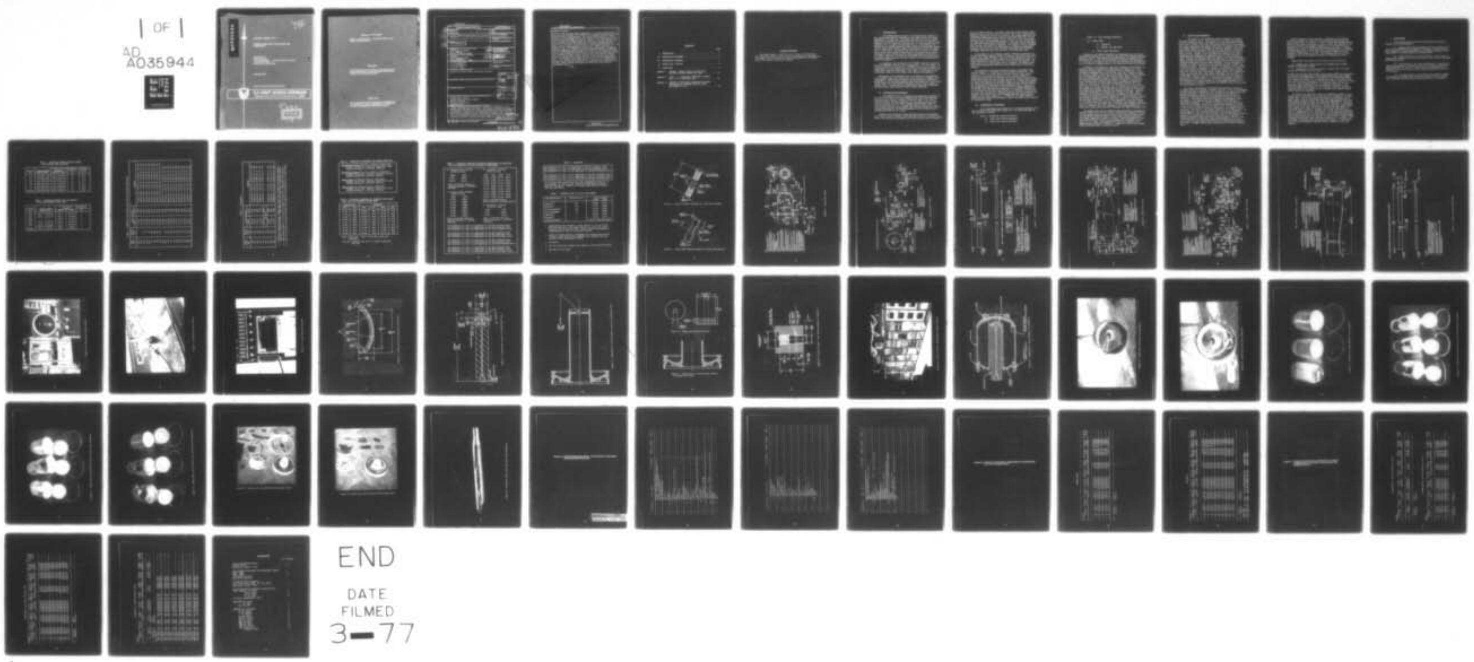

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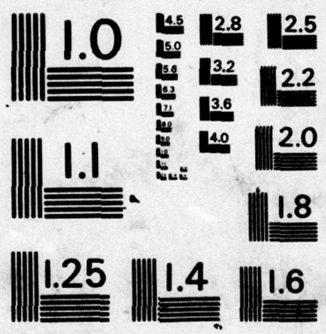

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TECHNICAL REPORT RK-7T-3

STINGER LAUNCH AND FLIGHT MOTOR CASE EVALUATION

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US Army Missile Research, Development and Engineering Laboratory
US Army Missile Command
Redstone Arsenal, Alabama 35809

September 1976

U.S. ARMY MISSILE COMMAND
Redstone Arsenal, Alabama 35809

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SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

REPORT DOCUMENTATION PAGE

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14

1. REPORT NUMBER
RK-7T-3

2. GOVT ACCESSION NO.

3. RECIPIENT'S CATALOG NUMBER

9

4. TITLE (and Subtitle)

6

STINGER LAUNCH AND FLIGHT MOTOR CASE EVALUATION.

5. TYPE OF REPORT & PERIOD COVERED
Technical Report,

6. PERFORMING ORG. REPORT NUMBER
RK-7T-3

7. AUTHOR(s)

10

James W. Wright, Jr

8. CONTRACT OR GRANT NUMBER(s)

9. PERFORMING ORGANIZATION NAME AND ADDRESS
Commander
US Army Missile Command
Attn: DRSMI-RK
Redstone Arsenal Ala 35809

10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS

16

DA 1X264306D646
AMCMS 634306.12.04600

11. CONTROLLING OFFICE NAME AND ADDRESS
Commander
US Army Missile Command
Attn: DRSMI-RPR
Redstone Arsenal Ala 35809

11

12. REPORT DATE
Sep [redacted] 1976

13. NUMBER OF PAGES
54

14. MONITORING AGENCY NAME & ADDRESS(if different from Controlling Office)

12 56p.

15. SECURITY CLASS. (of this report)
Unclassified

15a. DECLASSIFICATION/DOWNGRADING SCHEDULE

16. DISTRIBUTION STATEMENT (of this Report)

Approved for public release; distribution unlimited.

ACCESSION for	
NTIS	White Section
DDC	Buff Section
UNANNOUNCED	
JUSTIFICATION	
BY	
DISTRIBUTION/AVAILABILITY CODES	
Dist.	AVAIL. and/or SPECIAL
A	

17. DISTRIBUTION STATEMENT (of the abstract entered in Block 20, if different from Report)

18. SUPPLEMENTARY NOTES

19. KEY WORDS (Continue on reverse side if necessary and identify by block number)

Stinger missile system
Integral separation piston assembly
Dynamic burst tests
300 grade maraging steel
Hydroburst tests

20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

An investigation was initiated to evaluate the acceptability of the STINGER launch and flight motor cases. These efforts consisted of evaluating the mechanical properties of the 300 grade maraging steel launch and flight case material by tensile tests and evaluating the strength of the launch and flight cases by hydroburst and the launch cases by dynamic burst. The dynamic burst was accomplished by loading the launch cases with carpet roll (HEN-12) propellant and static firing in a fixture in which the nozzles were partially

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ABSTRACT (Concluded)

constricted thus causing a rapid (approximately 3 to 5 msec) pressure rise to burst due to the hot gases. The purpose was to determine the burst stress under simulated static firing conditions. The results indicate that the 0.127-mm (0.005-in.) radius Ortman keys gave more reliable data resulting in a burst of the case itself (thus fully utilizing the strength of the case material) rather than a separation at the case/closure key joint due to the case expanding up and over the key radius. The dynamic burst pressure~~, therefore,~~ for the launch motor cases with 0.127-mm (0.005-in.) radius keys was 5.254 MPa (762 psi) higher than the standard hydroburst pressure of 54.248 MPa (7868 psi), an increase of 10%. The STINGER launch motor system reliability at the expected operating conditions is thereby increased significantly because the design was based on standard hydroburst strength. The results for the flight motor cases tested in this program reflected problems with the thread design of the forward joint although the results from one test and others from Atlantic Research Corporation indicate that the burst pressure is certainly well above requirements. The strength of the flight motor case could be reduced significantly and, in fact, should be if possible because of the potential of failure due to marginal fracture toughness capability. An undetected flaw or especially one introduced after the proof test during the service life could result in catastrophic failure.

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CONTENTS

ACKNOWLEDGEMENT

The author wishes to thank Mr. John M. Tate of the Propulsion Motor and Power Function and his group for performing the hydrotesting and dynamic burst testing and Mr. Maximillian Rhoden for his assistance in the computer statistical analysis.

I. INTRODUCTION

The STINGER missile system is a shoulder-fired, surface-to-air, antiaircraft missile consisting of two stages (launch and flight) assembled in a launch tube. The launch motor burns out in the launch tube before the missile is ejected from the tube; then the launch motor separates from the flight motor during coast to a safe distance from the operator prior to ignition of the flight motor. This separation is actuated by an integral separation piston assembly which becomes pressurized at launch motor burnout, shears retaining pins holding the launch motor to the missile, and retards the launch motor velocity. The dual thrust flight motor provides propulsion for the missile during flight to the target. Thrust during the boost phase accelerates the missile to a velocity sufficient to accomplish the STINGER system mission and then the sustain phase maintains the boost velocity for a time sufficient to fulfill the mission.

It is apparent that the design of the STINGER propulsion system is one of considerable complexity and sophistication. For this reason, the Propulsion Directorate initiated, at STINGER Project Office request, an investigation of the complete propulsion system including the launch and flight motor cases and propellants. This report is restricted to the case effort; however, a later report will address the propellants.

The purpose of the evaluation was to determine the acceptability of the STINGER launch and flight motor cases relative to STINGER system requirements. These efforts consisted of determining the mechanical properties of the 300 grade maraging steel case material and the strength of the launch and flight cases by hydroburst and the launch cases by dynamic burst. The purpose of the dynamic burst tests was to determine the burst stress under simulated static firing conditions.

II. MATERIALS AND EQUIPMENT

The materials used in evaluating the mechanical properties of the launch and flight motor case maraging steel (300 grade) materials were furnished by Atlantic Research Corporation (ARC) in the form of round bar tensile specimens (Figure 1) for the launch case and sheet tensile specimens cut from actual Marquardt flight cases (Figure 2) with the curvature left in. All specimens were received in the fully heat-treated condition having already been solution annealed and aged in a steam environment by the standard practices of 816°C (1500°F) for 1 hour and 482°C (900°F) for 4 hours.

Maraging steel launch and flight (Marquardt and Norris Thermador) motor cases, forward closures, and Ortman Keys (Figures 3 through 9) were used in the hydroburst and dynamic burst tests and were also furnished by

ARC in the aged condition. The launch cases and forward closures were machined from bar stock by ARC and therefore had no cold working (strain hardening) associated with their properties. The launch cases were also "once-fired" having been proof tested at 29.992 MPa (4350 psi) and then fired at -40.1°C (-40°F) ambient or 60°C (+140°F). On the other hand, the flight cases had significant amounts of cold work left in them after the last shear spinning pass (Marquardt) or deep draw (Norris-Thermador) which had not been removed by annealing. The reason it was not annealed after the last cold work cycle was because of problems of dimensional tolerance controls for the very thin-wall case during heat treatment, The flight cases had been proof-tested at 27.992 MPa (4060 psi).

The equipment for the material property evaluation consisted of a Tinius Olsen tensile machine (Figure 10) and S-2 type Tinius Olsen extensometer (2-in. gauge length) for the curved sheet material and an S-3 type extensometer (1-in. gauge length) for the round bar specimens. The Tinius Olsen tensile machine has a 27,216 kg (60,000 lb) capacity, the loads applied by a screw-actuated moving crosshead. The stress-strain curves were automatically plotted on the attached Model 51 Electronic Recorder.

The hydroburst tests were conducted by using a hydrostatic test facility (Figure 11) constructed by the Propulsion Directorate. This facility consists of an air-driven hydraulic (water) pump, pressure transducer, and a Model 80A Mosely X-Y strip recorder (Figure 12). Fixtures were fabricated for sealing the nozzles in the aft end of the launch case (Figure 13) and the inner case of the forward closure (Figure 14) which had previouly been modified (Figure 15) to accept the fixture. The flight case hydroburst tests were conducted using a fixture (Figure 16) to replace the nozzle which had an Ortman key and "O" ring slots and through which was drilled a 4.762 mm (3/16-in.) pressurization port. The dynamic burst testing was accomplished by a different modification to the forward closure inner case (Figure 17) consisting of cutting off the inner case and sealing a pressure transducer (Kistler Standard Flush Mounting type) (Figure 18) in the remaining stub with another fixture (similar to the one in Figure 14). A 3700B Bell and Howell Magnetic Analog Recorder (Figure 19) was used to record the dynamic burst pressure as a function of time.

III. EXPERIMENTAL PROCEDURE

This investigation was divided into two phases according to the type of test and then subdivided further as to the source and type of test specimens as follows:

Phase I - Mechanical Property Evaluation

a) Launch case tensile evaluation

b) Flight case tensile evaluation

Phase II - Burst Strength Evaluation

a) Launch cases

1) Hydroburst

2) Dynamic (hot gas) burst

b) Flight cases, Hydroburst

In Phase I, the tensile evaluation was performed using the Tinius Olsen tensile machine and the round bar and curved sheet tensile specimens (Figures 1 and 2). The testing was accomplished at a crosshead rate of 5.08 mm/min (0.2 in./min) and the percent of elongation was determined for a 25.4 mm (1-in.) gauge section for the round bar launch case specimens and for a 50.8 mm (2-in.) gauge section for the curved sheet flight case specimens

In Phase II, the hydroburst tests were conducted on the facility of Figure 11 using the fixtures and modification of Figures 13 to 15 by attaching the motor cases to the pressure fitting (Figure 11). This particular arrangement was for the launch case, but a similar one with the fixture of Figure 15 was used for the flight case. Prior to loading into the hydroburst facility, the modified launch cases of Figure 14 were grit blasted lightly inside to remove firing residue. They were then pressure sealed by potting the fixture of Figure 12 into the aft end of the case with silicone rubber and by attaching the fixture of Figure 13 resulting in a test-ready configuration (Figure 20). The cases were then filled with water, the "O" ring was put in place with a small amount of silicone lubricant, and the closure was inserted. After the closure was in place, two retainer pins were pressed in to restrict the closure from twisting radially with respect to the case. Then the Ortman key was driven in the keyway with a hammer (by hand). After attachment to the hydroburst test system, the excess air was bled off and the motor placed in a bucket (Figure 21) to restrict debris at burst. The hydroburst pressurization was applied at a rate of 5.723 MPa/sec (830 psi/sec) for a burst in 5 to 10 sec (depending on the burst level) for the launch cases and a rate of 0.793 MPa/sec (115 psi/sec) to burst in 30 to 50 sec for the flight cases. The motor case assembly after burst shows the hydraulic line still attached to the closure (Figure 22). Launch motor cases before and after hydroburst are shown in Figures 23-26.

The dynamic burst tests of Phase II were conducted by utilizing the modified launch motor case and pressure transducer of Figures 17 and 18 and then loading a charge of approximately 0.04 kg (0.088 lb) of HEN-12 carpet-roll propellant inside the motor. During static firing, the nozzles were almost completely blocked by a fixture having an assembly of pins which restricted the hot gas flow and resulted in a pressure rise to burst in 4 to 5 msec. The pressure-time data were recorded on the Magnetic Analog Recorder of Figure 19. Launch motor cases after dynamic burst testing are shown in Figures 27 and 28.

IV. RESULTS AND DISCUSSION

The results of the mechanical property evaluation of Phase I are shown in Tables 1 and 2. These results for the launch case maraging steel are completely typical for maraging steel bar stock heat treated as this was. However, the flight case steel properties are much greater than those required and much greater than those for maraging steel having the optimum combination of strength and fracture toughness. The yield and ultimate tensile strengths are both very high because a significant amount of cold work was left in the flight case after the last pass of shear spinning. Normally, when the additional strength due to strain hardening is not required, the worked part would be fully annealed or strain relieved and then heat treated by aging to the desired strength level. However, the STINGER flight case thickness is such a thin section, nominally 0.609 mm (0.024 in.), that tolerance control difficulties precluded annealing after the last shear spin pass. It was considered too difficult to control distortion so the decision was made to accept the increased strength. This has the potential for fracture control problems in that the fracture toughness (a measure of the ability to tolerate structural defects like cracks) is so low that should a defect develop after proof testing, then catastrophic failure could occur. Because the flight case does not have a man-rating requirement, the occurrence of a catastrophic failure means the loss of the mission but not injury or loss of life. However, even if no failure occurs, methods do exist to demonstrate that the reliability of the flight system must suffer due to the extremely high strength because of the increased likelihood of a defect growing to a critical size during the STINGER system's service life and causing mission failure.

The results and analyses of the dynamics and hydroburst testing of the launch cases are presented in Tables 3 through 6. One of the purposes of these tests was to determine if the strength of the launch cases under dynamic conditions is higher than that for hydrotest conditions. A statistical analysis computer routine (Appendix A) was utilized to determine if there was a significant difference between the two test techniques. The detailed results are presented in Appendices B and C. The results of the analysis as seen in Tables 4 and 5 indicate no significant difference. It should be pointed out, however, that it is very likely the dynamic testing does significantly increase the burst strength, but for this population of data, it will be noticed that most of the 0.127-mm (0.005-in.) keys were included in the hydroburst subpopulation. The effect of the smaller radius key (to be discussed in the next paragraph) is an increased weighting of the average hydroburst results (Table 5, Part 2) to such an extent that the statistical analysis considers it insignificant, concluding that there is no difference between hydrotesting and dynamic burst testing (Table 5, Part 1). The 0.127-mm (0.005-in.) radius keys increase the hydroburst to such an extent that the large number of data points for these simply overwhelm the effect of dynamic testing which utilized mostly 0.254-mm (0.010-in.) keys.

Another purpose of these tests was to determine if the 0.127-mm (0.005-in.) Ortman keys or the 0.254-mm (0.010-in.) keys increase the burst pressure more. A comparison of each of these keys was made and the results of the analysis are shown in Tables 4 and 6. The results for the 0.127-mm (0.005-in.) key dynamic compared to the 0.254-mm (0.010-in.) dynamic (1 to 3) show a significant difference at all levels. Likewise, the comparison of the 0.127-mm (0.005-in.) key hydroburst to the 0.254-mm (0.010-in) hydroburst (2 to 4) shows a significant difference at all confidence levels except the 99.9%. This indicates that the 0.127-mm (0.005-in.) key has the greatest influence on increasing the burst strength.

These results then lead to the following two-fold conclusion:

1) Dynamic burst testing results in increased burst strength compared to hydroburst testing.

2) Ortman Keys of 0.127-mm (0.005-in.) radius result in higher bursts than 0.254-mm (0.010-in.) keys.

However, the conclusion that dynamic testing gives higher burst strengths is clouded by the comparision of the 0.254-mm (0.010-in.) key dynamic burst to the 0.254-mm (0.010-in.) hydroburst (3 to 4) where no significant difference is shown. It is believed that this is a further reflection of the inferior performance of 0.254-mm (0.010-in.) keys which results in a very large standard deviation of 11.804 MPa (1690 psi) for the hydroburst results and masks the true significant difference. Had sufficient data been available for the 0.254-mm (0.010-in.) hydroburst, it would probably lend credence to the conclusion that dynamic testing yields higher burst strengths.

The flight case hydroburst results are presented in Table 7; it is evident that any discussion and conclusions must of necessity be based on minimal data. This in turn causes some degree of uncertainty, but it seems evident from the limited data that the flight case does have more than adequate strength to meet its operational requirements. The burst pressures 40.302 MPa (5770 psi) and 40.511 MPa (5800 psi) for Marquardt cases and the 44.157 MPa (6322 psi) for Norris cases are in fact significantly higher than those required thus verifying the same results for the tensile data in Phase I. However, the low data reported were a result of leaking around the threaded joints rather than burst emphasizing some inadequacies of the joint design. It was determined that these latter cases did not have the tightened tolerance buttress thread design which ARC had initiated; this accounts for the low data. Figure 29 shows a Marquardt shear-spun flight case after hydroburst; it is evident from the number of missing pieces that shattering occurred — further indication of the brittleness or minimal fracture toughness of the case material.

V. CONCLUSIONS

The following conclusions are listed based on the results obtained in this investigation:

a) Dynamic burst testing increases the burst strength of the launch case approximately 10% compared to hydroburst testing; however, this conclusion is confounded because of the weighting influence of the large number of 0.127-mm (0.005-in.) hydroburst data.

b) Ortman keys with a 0.127-mm (0.005-in.) radius result in higher burst pressures than 0.254-mm (0.010-in.) keys for both the dynamic and hydroburst tests.

c) The strength of the flight case material is significantly higher than necessary, as determined in both the tensile specimens and case hydroburst, and results in a case which is nonforgiving to the presence of defects and could portend problems during the service life of the system.

d) The specification for the flight case should be changed to incorporate a maximum yield and ultimate tensile strength requirement to alleviate the potential problems mentioned in c) previously.

TABLE 1. MECHANICAL PROPERTY DATA FOR LAUNCH CASE MARAGING STEEL BAR STOCK.

Specimen No.	Yield Strength		Ultimate Tensile Strength		Elongation 50.8 (2 in.) (%)	Reduction of Area (%)
	(MPa)	(psi)	(MPa)	(psi)		
201	1909.8	277,000	1982.2	287,500	6.5	29.3
202	1878.8	272,500	1940.9	281,500	7.0	30.4
203	1861.6	270,000	1923.6	279,000	7.0	27.8
204	1882.2	273,000	1920.2	278,500	8.0	30.1
205	1906.4	276,500	1971.9	286,000	7.0	30.6
Average	1887.8	273,800	1947.1	282,400	7.1	29.6

TABLE 2. MECHANICAL PROPERTY DATA FOR MARAGING STEEL FROM MARQUARDT FLIGHT CASE

Specimen No.	Yield Strength		Ultimate Tensile Strength		Elongation 50.8 mm (2-in.) (%)
	(MPa)	(psi)	(MPa)	(psi)	
MF01	2306.7	334,560	2347.2	340,440	1
MF02	2283.2	331,160	2328.2	337,680	1
MF03	---	---	2254.6	327,010	1
MF04	2224.9	322,700	2259.1	327,660	1
MF05	2206.3	320,000	2272.7	329,630	1
Average	2255.3	327,110	2292.4	332,480	1

TABLE 3. HYDROBURST AND DYNAMIC BURST DATA FOR LAUNCH MOTOR CASES

Case Serial No.	Closure Serial No.	Burst Pressure (MPa)	Burst Pressure (psi)	Remarks
0022	-	40.541	5880	Dynamic Burst, 0.254 mm, (0.010 in.) R. Key
0140	-	41.368	6000	Dynamic Burst, 0.254 mm, (0.010 in.) R. Key
0349	25	45.215	6558	Dynamic Burst, 0.254 mm, (0.010 in.) R. Key
0555	34	46.884	6800	Dynamic Burst, 0.254 mm, (0.010 in.) R. Key
0591	44	45.781	6640	Dynamic Burst, 0.254 mm, (0.010 in.) R. Key
497	009	60.522	8778	Dynamic Burst, 0.127 mm, (0.005 in.) R. Key
302	002	58.426	8474	Dynamic Burst, 0.127 mm, (0.005 in.) R. Key
498	090	46.484	6742	Dynamic Burst, 0.254 mm, (0.010 in.) R. Key
468	007	44.064	6391	Dynamic Burst, 0.254 mm, (0.010 in.) R. Key
0144	-	28.820	4180	Hydroburst, 0.254 mm, (0.010 in.) R. Key
0153	036	45.298	6570	Hydroburst, 0.254 mm, (0.010 in.) R. Key
492	023	48.952	7100	Hydroburst, 0.127 mm, (0.005 in.) R. Key[1]
017	087	53.089	7700	Hydroburst, 0.127 mm, (0.005 in.) R. Key
016	003	55.089	7990	Hydroburst, 0.127 mm, (0.005 in.) R. Key
005	005	53.779	7800	Hydroburst, 0.127 mm, (0.005 in.) R. Key[1]
028	016	55.847	8100	Hydroburst, 0.127 mm, (0.005 in.) R. Key[1]
070	109	51.710	7500	Hydroburst, 0.127 mm, (0.005 in.) R. Key
052	104	54.468	7900	Hydroburst, 0.127 mm, (0.005 in.) R. Key
002	024	53.434	7750	Hydroburst, 0.127 mm, (0.005 in.) R. Key
022	063	56.192	8150	Hydroburst, 0.127 mm, (0.005 in.) R. Key

TABLE 3. (Concluded).

Case Serial No.	Closure Serial No.	Burst Pressure		Remarks
		(MPa)	(psi)	
038	076	36.542	5300	Hydroburst, 0.127 mm, (0.005 in.) R. Key[2]
058	044	54.123	7850	Hydroburst, 0.127 mm, (0.005 in.) R. Key
048	041	57.571	8350	Hydroburst, 0.127 mm, (0.005 in.) R. Key
012	020	53.434	7750	Hydroburst, 0.127 mm, (0.005 in.) R. Key
011	010	52.744	7650	Hydroburst, 0.127 mm, (0.005 in.) R. Key
009	114	No test[3]		
013	006	55.847	8100	Hydroburst, 0.127 mm, (0.005 in.) R. Key
004	045	57.916	8400	Hydroburst, 0.127 mm, (0.005 in.) R. Key
068	057	53.779	7800	Hydroburst, 0.127 mm, (0.005 in.) R. Key

1. Difficulty encountered with leakage past nozzle seal during first attempt (bubbles observed in silicone rubber). Burst data are for retest after replacing siliconc.
2. Deep scratch appeared to be point of origin of fracture; eliminated from analysis.
3. Burr in key groove prevented complete key insertion and resulted in "O" ring failure.

TABLE 4. COMPARISON OF HYDROBURST AND DYNAMIC BURST DATA

Hydroburst Pressure [0.254-mm, (0.010-in.) radius key]
Average = 37.059 MPa, (5375 psi) (based on 2 tests)
Standard Deviation = 11.652 MPa, (1690 psi)

Hydroburst Pressure [0.127-mm (0.005-in.) radius key]
Average = 54.248 MPa, (7868 psi) (based on 16 tests)
Standard Deviation = 2.220 MPa, (322 psi)

Dynamic Burst [0.254-mm (0.010-in.) radius key]
Average = 44.333 MPa, (6430 psi) (based on 7 tests)
Standard Deviation = 2.489 MPa, (361 psi)

Dynamic Burst [0.127-mm (0.010-in.) radius key]
Average = 59.474 MPa, (8626 psi) (based on 2 tests)
Standard Deviation = 1.482 MPa, (215 psi)

TABLE 5. STATISTICAL COMPARISON OF HYDROBURST AND DYNAMIC BURST DATA FOR DIFFERENCE BETWEEN MEANS

Dynamic Burst		Hydroburst			
(MPa)	(psi)	(MPa)	(psi)	(MPa)	(psi)
40.541	5880	28.820	4880	53.434	7750
41.368	6000	45.299	6570	56.192	8150
45.216	6558	48.953	7100	54.124	7850
46.884	6800	53.090	7700	57.571	8350
45.781	6640	55.089	7990	53.434	7750
60.522	8778	53.779	7800	52.745	7650
58.426	8474	55.848	8100	55.848	8100
46.484	6742	51.711	7500	57.916	8400
44.064	6391	54.469	7900	53.779	7800

Mean = 44.333 MPa, (6430 psi) — Mean = 52.338 MPa, (7591 psi)

Std. Dev. = 2.489 MPa (361 psi) — Std. Dev. = 6.578 MPa, (954 psi)

TABLE 6. STATISTICAL COMPARISON OF VARIOUS COMBINATIONS OF BURST TEST TYPE AND ORTMAN KEY TYPE FOR DIFFERENCE BETWEEN MEANS.

1) Dynamic Burst, 0.127-mm (0,005-in.) Key*

(MPa)	(psi)
60.522	(8778)
58.426	(8474)

Mean = 59.474 MPa (8626 psi)
Standard Deviation = 2.489 MPa (361 psi)

2) Dynamic Burst, 0.254-mm (0.010-in.) Key

(MPs)	(psi)
40.541	(5880)
41.368	(6000)
45.216	(6558)
46.884	(6800)
45.781	(6640)
46.484	(6742)
44.064	(6391)

Mean = 44.333 MPa (6430 psi)
Standard Deviation = 2.489 MPa (361 psi)

3) Hydroburst, 0.127-mm (0.005-in.) Key

(MPa)	(psi)	(MPa)	(psi)
49.853	(7100)	56.192	(8150)
53.090	(7700)	54.124	(7850)
55.089	(7990)	57.571	(8350)
53.779	(7800)	53.434	(7750)
55.848	(8100)	52.745	(7650)
51.711	(7500)	55.848	(8100)
54.459	(7900)	57.916	(8400)
53.434	(7750)	53.779	(7800)

Mean = 54.248 MPa (7868 psi)
Standard Deviation 2.220 MPa (322 psi)

4) Hydroburst, 0.254-mm (0.010-in.) Key*

(MPa)	(psi)
28.820	(4180)
45.299	(6570)

Mean = 37.059 MPa (5375 psi)
Standard Deviation = 11.652 MPa (1690 psi)

The difference of 1 and 2 is significant at the 90% confidence level.
The difference of 1 and 2 is significant at the 95% confidence level.
The difference of 1 and 2 is significant at the 99.9% confidence level.

The difference of 1 and 3 is significant at the 90% confidence level.
The difference of 1 and 3 is significant at the 95% confidence level.
The difference of 1 and 3 is significant at the 99.9% conifdence level.

The difference of 1 and 4 is significant at the 90% confidence level.
The difference of 1 and 4 is significant at the 95% confidence level.
The difference of 1 and 4 is not significant at the 99.9% confidence level.

The difference of 2 and 3 is significant at the 90% confidence level.
The difference of 2 and 3 is significant at the 95% confidence level.
The difference of 2 and 3 is significant at the 99.9% confidence level.

TABLE 6. (Concluded)

The difference of 2 and 4 is significant at the 90% confidence level. The difference of 2 and 4 is significant at the 95% confidence level. The difference of 2 and 4 is not significant at the 99.9% confidence level.
The difference of 3 and 4 is not significant at the 90% confidence level. The difference of 3 and 4 is not significant at the 95% confidence level. The difference of 3 and 4 is not significant at the 99.9% confidence level.

*It is obvious that insufficient data (and considerable scatter for 4) are available for these to prove statistical significance; however, these data do seem to indicate a difference which should be verified with more data points.

TABLE 7. HYDROBURST DATA FOR FLIGHT MOTOR CASES.

Case Manufacturer	Case Serial No.	Burst Pressure (MPa)	(psi)
Marquardt[1]	294	39.782	(5770)
Marquardt[1]	240	29.509	(4280)
Norris-Thermador[2]	096	26.200	(3800)
Norris-Thermador[2]	156	33.095	(4800)
Marquardt[3]	---	39.989	(5800)
Marquardt[4]	---	28.576	(4145)
Norris-Thermador[5]	---	31.847-43.588	(4619-6322)

1. Leaked during first attempt at nozzle fixture "0" ring at 30.337 MPa (4400 psi) and at the forward closure "0" ring on the second attempt at 35.646 MPa (5170 psi). Third attempt using oversize "0" rings resulted in burst in cylindrical section.

2. Failed at forward closure by expanding over threaded area allowing closure to eject and strip the threaded joint slightly thus preventing further pressurization tests.

3. ARC tests.

4. ARC test which had a pressure leak similar to 2 (mentioned previously).

5. ARC tests of five cases.

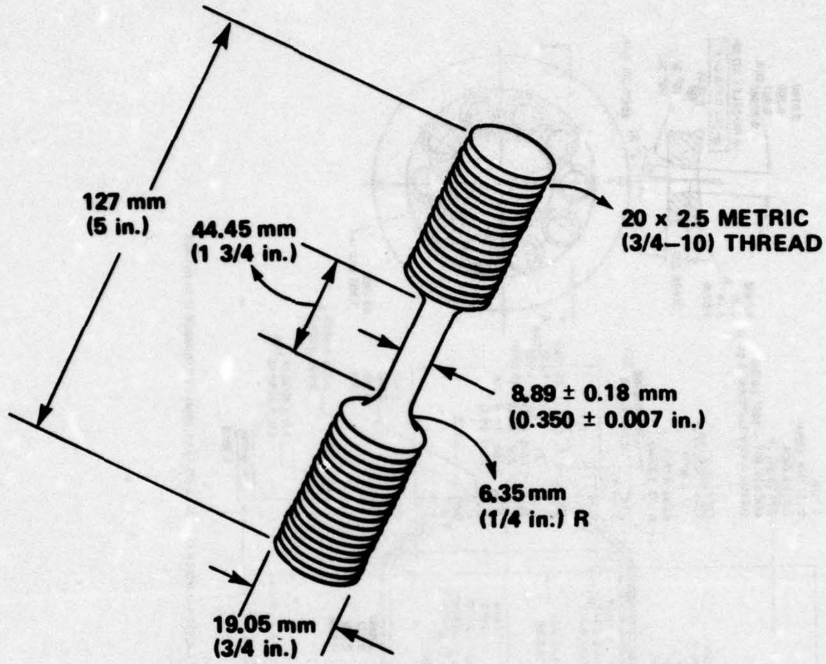


Figure 1. Round bar tensile specimen for launch case material.

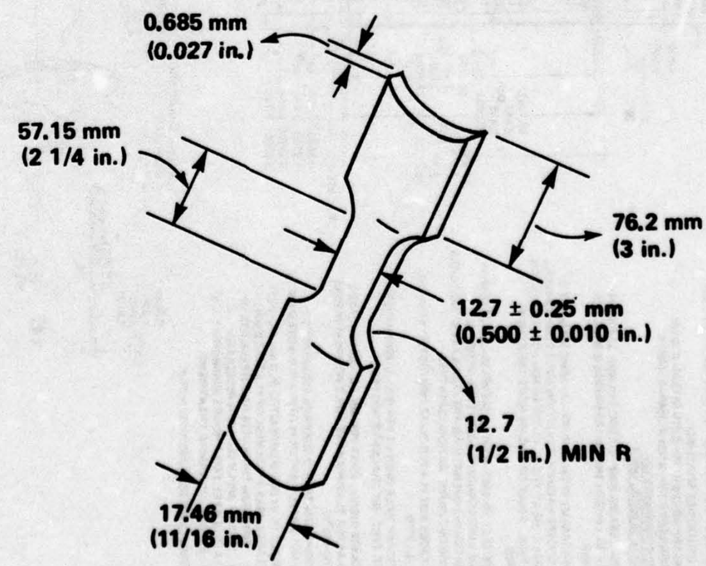


Figure 2. Curved sheet tensile specimen for flight case material.

NOTES:

1 INTERPRET DRAWING IN ACCORDANCE WITH MIL–D–1000 CATEGORY E, FORM 3.

2 VIBRAETCH PART NO. A0079132 DASH NO., REV LTR AND NON RECURRING SERIAL NO. IN AREA INDICATED. 170°–190° FROM 0.134 SLOT IN ACCORDANCE WITH MIL–STD–130. BEFORE PLATING PER NOTE 9 OR 11.

3 UNLESS OTHERWISE SPECIFIED:
BREAK SHARP EDGES 0.005–0.015 (0.1270–0.3810)
INSIDE CORNERS 0.010–0.020 (0.2540–0.5080) R
SURFACE ROUGHNESS 125
ALL DIA ⌭ A 0.005 (0.1270)

4 THE 2.585–2.587 (65.6590–65.7098) DIA AND 63 FINISH APPLIES FOR LENGTH SHOWN. REMAINDER SHALL BE 2.580–2.587.

5 MATL: MARAGING STEEL PER MIL–S–46850 GRADE 300, TYPE III EXCEPT VACUUM INDUCTION MELT PLUS VACUUM ARC REMELT. HEAT TREAT TO 285 ksi MIN UTS AND 5% MIN ELONGATION. A MAX OF 4 HOUR HEAT TREATMENT PERMITTED.

6 PRESSURE TEST TO 4350–4400 psi (29,993.25–30,338.00) FOR 5 sec IN AN UNRESTRAINED CONDITION AFTER ALL MANUFACTURING OPERATIONS ARE COMPLETED. NO LEAKS OR PERMANENT DEFORMATION PERMITTED.

7 ALL SURFACES NOT PLATED TO BE PROTECTED WITH OIL PER MIL–L–3150.

8 MAGNETIC PARTICLE INSPECT PER MIL–I–6868 AFTER PRESSURE TEST. NO CRACKS PERMITTED.

9 ELECTROLESS NICKEL COAT PER MIL–C–26074 CLASS 2 GRADE B AFTER PLATING BAKE FOR 3 HOURS MINIMUM AT 375° TO 400°F.

10. DIMENSIONAL LIMITS AND SURFACE ROUGHNESS DESIGNATIONS APPLY AFTER PLATING PER NOTE 9 OR 11.

11 CADMIUM PLATE VACUUM DEPOSITED PER MIL–C–8837, TYPE II CLASS 2, MAX THICKNESS OF PLATING 0.0005 in (0.01270) MINIMUM THICKNESS REQUIREMENTS OF PLATING DO NOT APPLY ON AREA INDICATED .... AFTER PLATING BAKE FOR 3 HOURS MINIMUM AT 375° TO 400°F. BEFORE CHROMATE TREATMENT.

12. REQUIREMENTS OF SOAP A0079132 APPLY.

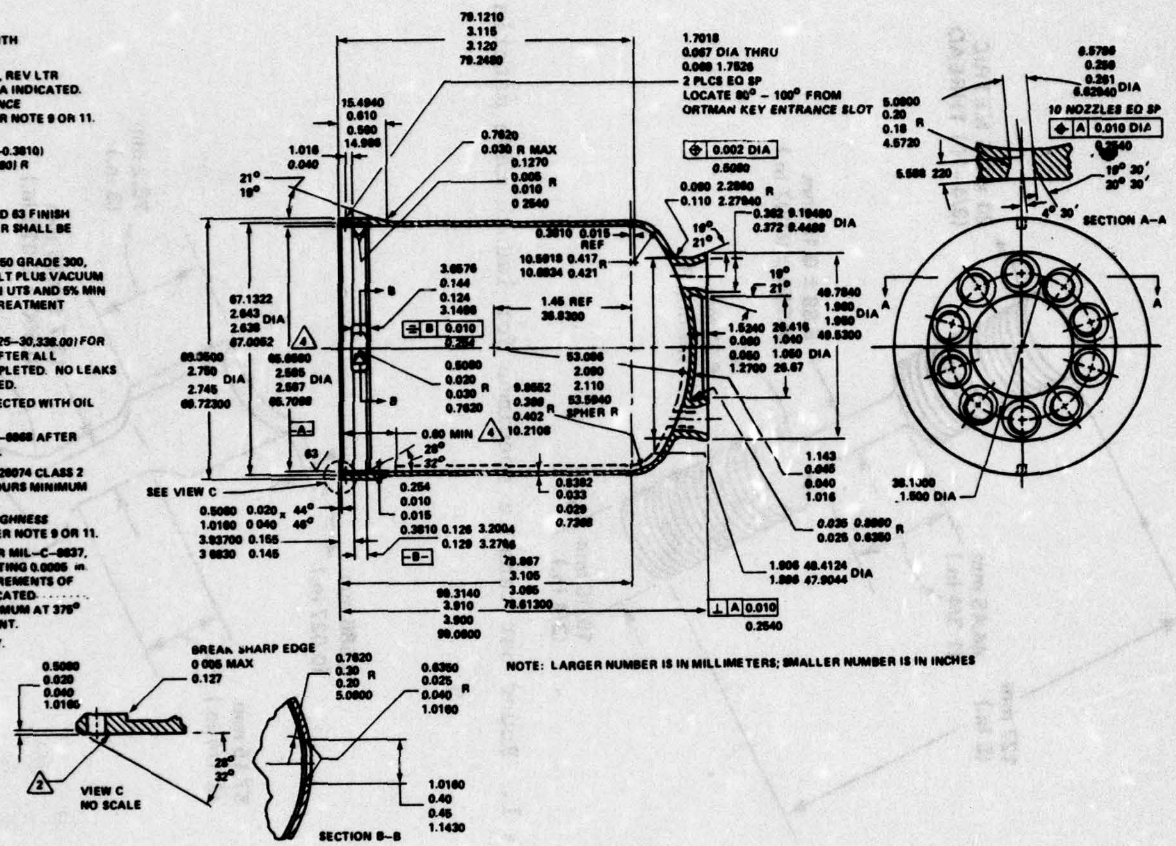


Figure 3. Launch motor case.

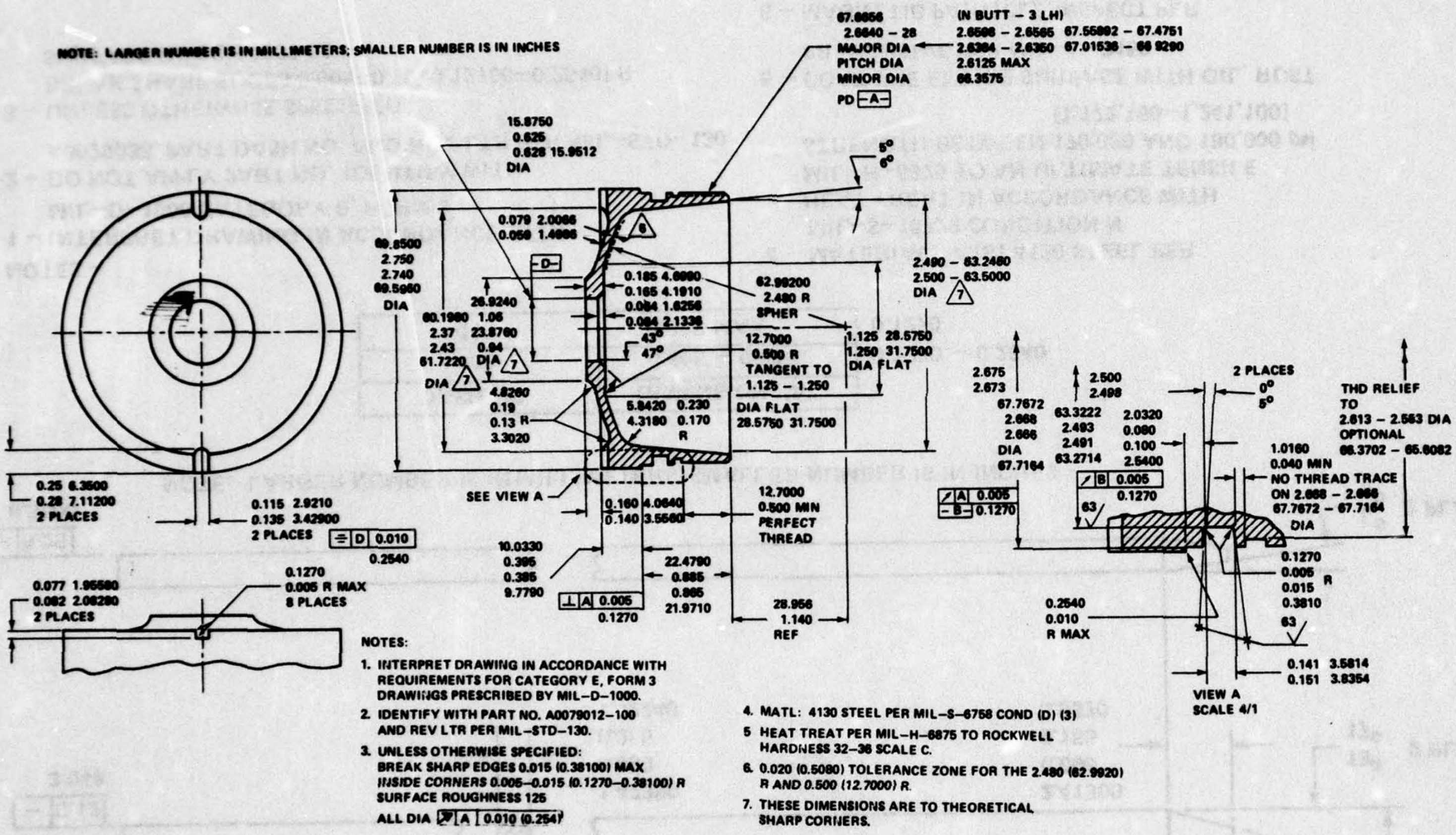
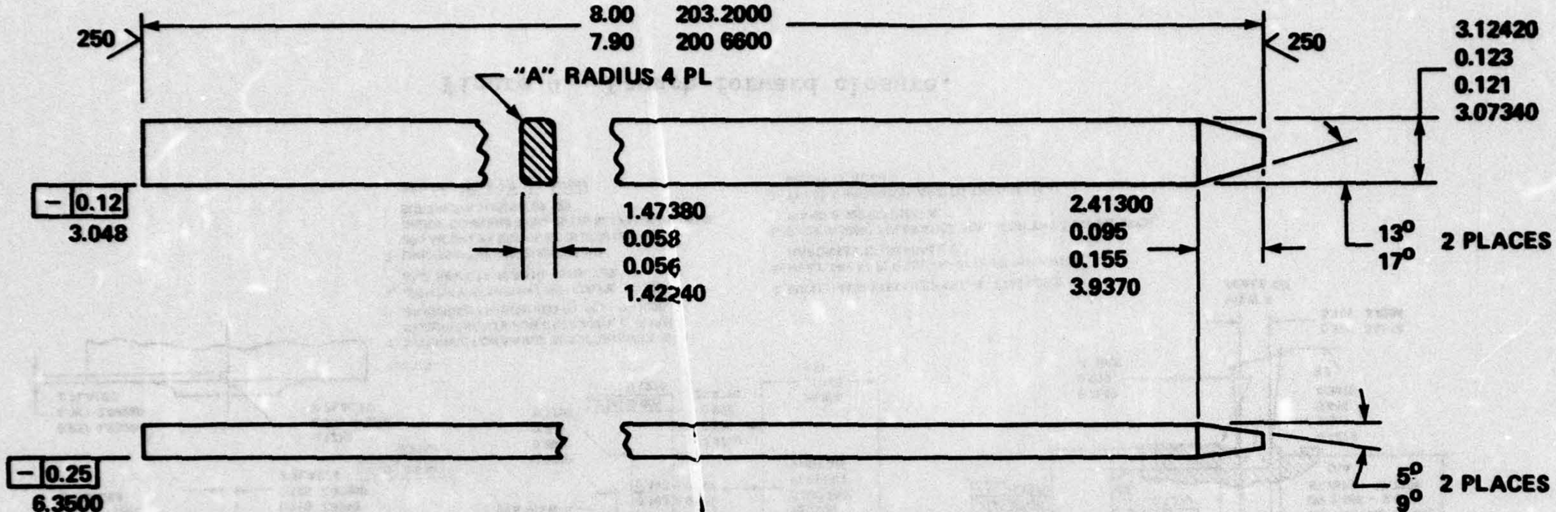


Figure 4. Launch forward closure.



NOTE: LARGER NUMBER IS IN MILLIMETERS; SMALLER NUMBER IS IN INCHES.

DASH NO.	DIMENSION "A"	
–100	0.005 – 0.010	0.1270 – 0.2540
–101	0.005 MAX	0.1270

NOTES –

1 – INTERPRET DRAWING IN ACCORDANCE WITH MIL–D–1000 CATEGORY E, FORM 3

2 – DO NOT APPLY PART NO. IDENTIFY WITH A0079033, PART DASH NO. AND REV LTR PER MIL–STD–130.

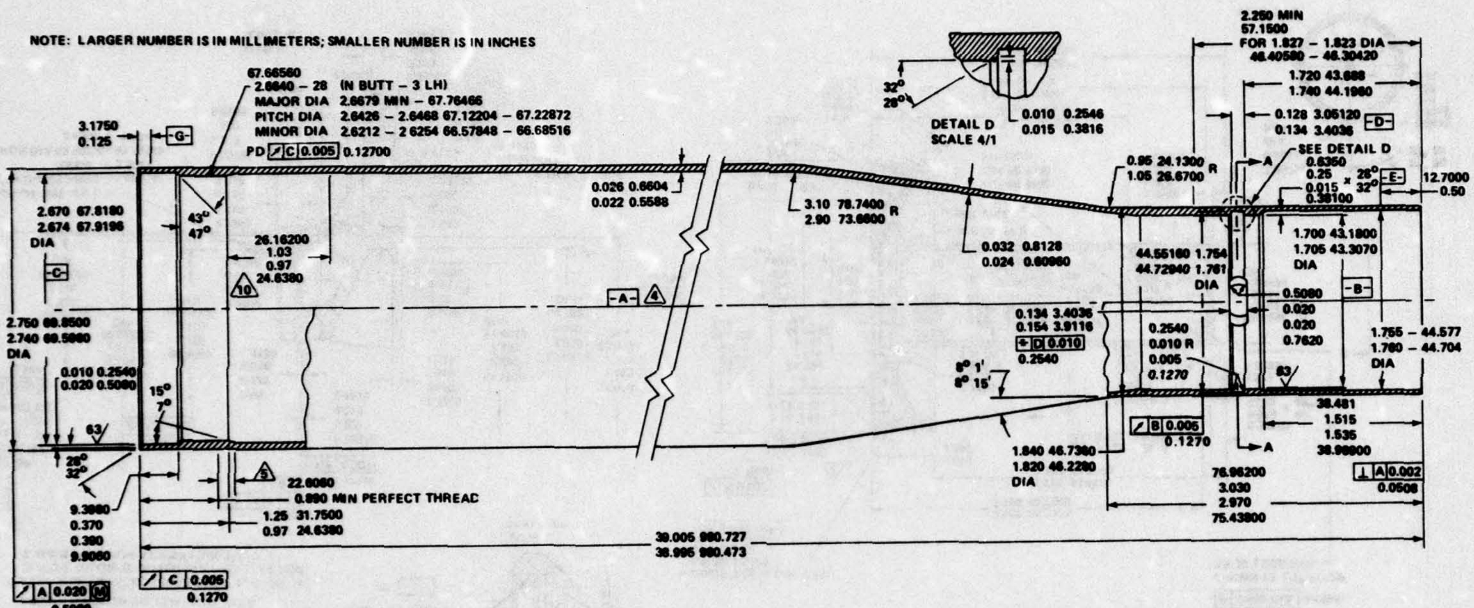
3 – UNLESS OTHERWISE SPECIFIED BREAK SHARP EDGES 0.005–0.10 (0.12700–0.2540) R SURFACE ROUGHNESS 63

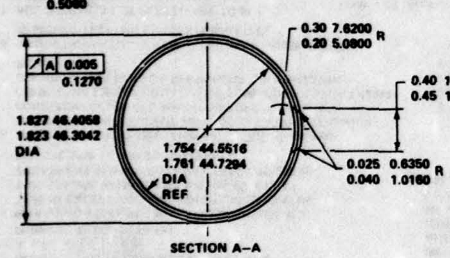
4 – MATERIAL: A1S1 4130 STEEL PER MIL–S–18729 CONDITION N. HEAT TREAT IN ACCORDANCE WITH MIL–H–6875 TO AN ULTIMATE TENSILE STRENGTH BETWEEN 170,000 AND 180,000 psi (1,172,150–1,241,100)

5 – COAT THE ENTIRE SURFACE WITH OIL, RUST PREVENTIVE PER MIL–L–3150

6 – MAGNETIC PARTICLE INSPECT PER MIL–I–6868. NO CRACKS PERMITTED.

Figure 5. Launch retaining Ortman key.





NOTES:

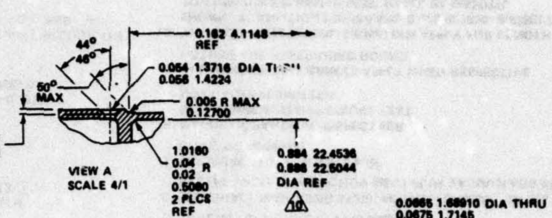
1. INTERPRET DRAWING IN ACCORDANCE WITH REQUIREMENTS FOR CATEGORY E, FORM 3 DRAWINGS PRESCRIBED BY MIL–D–1000.
2. IDENTIFY WITH PART NO. A0079030–100 AND REV LTR PER MIL–STD–130.
3. UNLESS OTHERWISE SPECIFIED:
BREAK SHARP EDGES 0.005–0.015 (0.1270–0.3810)
INSIDE CORNERS 0.010–0.020 (0.2540–0.5080) R
SURFACE ROUGHNESS 125
ALL DIA -A- 0.010 0.2540
4. DATUM –A– IS DEFINED AS A LINE PASSING THROUGH THE CENTER OF THE OUTSIDE DIA AT DATUM –G– AND –E– REGARDLESS OF FEATURE SIZE.
5. THREADS OPTIONAL IN THIS AREA
6. MATERIAL: MARAGING STEEL PER MIL–S–46850, GR 300 EXCEPT VACUUM INDUCTION MELT PLUS VACUUM ARC REMELT.
7. PRESSURE TEST PER NOTE 6 OF DRAWING A0079031
8. MAGNETIC PARTICLE INSPECT PER MIL–I–6868 AFTER PRESSURE TEST NO CRACKS PERMITTED.
9. ALL RUNOUT TOLERANCES APPLY WHEN RESPECTIVE DATUMS ARE RESTRAINED ROUND.
10. THE 0.030–0.025 (0.7620–0.6350) DIM APPLY FOR LENGTH SHOWN. TRANSITION FROM 0.030–0.025 (0.7620–0.6350) WALL TO 0.026–0.022 (0.6604–0.5588) SHALL BE SMOOTH.

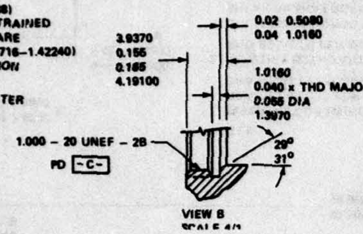
Figure 6. Flight motor case.

NOTES:

1. INTERPRET DRAWING IN ACCORDANCE WITH REQUIREMENTS FOR CATEGORY E FORM 3 DRAWINGS PRESCRIBED BY MIL–D–1000.
2. VIBRAETCH PART NO. A0079194 DASH NO., REV LTR AND NON–RECURRING SERIAL NO. IN AREA INDICATED IN ACCORDANCE WITH MIL–STD–130. BEFORE PLATING PER NOTE 8 OR 13.
3. UNLESS OTHERWISE SPECIFIED:
   BREAK SHARP EDGES 0.005–0.015 (0.12–0.38)
   INSIDE CORNERS 0.010–0.20 (0.25–0.508) R
   ALL DIA ⌰ A 0.005
   SURFACE ROUGHNESS 125
4. MARAGING STEEL PER MIL–S–46850 GRADE 300 TYPE III EXCEPT VACUUM INDUCTION MELT PLUS VACUUM ARC REMELT AND 4 HOUR MAX HEAT TREATMENT PERMITTED. HEAT TREAT TO 286 ksi MIN UTS AND 5% MIN ELONGATION.
5. PRESSURE TEST TO 4350–4400 psi (29,993.25–30,338) FOR 5 sec IN DIRECTION OF ARROWS IN AN UNRESTRAINED CONDITION AFTER ALL MACHINING OPERATIONS ARE COMPLETED EXCEPT DRILLING OF 0.054–0.056 (1.3716–1.42240) DIA HOLE. NO LEAKS OR PERMANENT DEFORMATION PERMITTED.
6. MAGNETIC PARTICLE INSPECT PER MIL–I–6868 AFTER PRESSURE TEST. NO CRACKS PERMITTED.
7. ALL SURFACES NOT PLATED ARE TO BE PROTECTED WITH OIL PER MIL–L–3150.
8. ELECTROLESS NICKEL COAT PER MIL–C–26074 CLASS 2, GRADE B. AFTER PLATING BAKE FOR 3 HOURS MINIMUM AT 375° TO 400°F.
9. DIMENSIONAL LIMITS AND SURFACE ROUGHNESS DESIGNATIONS APPLY AFTER PLATING PER NOTE 8 OR 13.
10. THICKNESS REQUIREMENTS OF PLATING PER NOTE 8 DO NOT APPLY ON 0.885 (22.479) DIAMETER.
11. DIMENSION APPLIES FOR LENGTH SHOWN.
12. A 63 FINISH PERMITTED IN AREA INDICATED.
13. CADMUIM PLATE, VACUUM DEPOSITED PER MIL–C–8837 TYPE II, CLASS 2 MAXIMUM THICKNESS OF PLATING OF PLATING DO NOT APPLY ON 0.885 (22.479) DIA AFTER PLATING AND BEFORE APPLICATION OF TYPE II (CHROMATE) TREATMENT BAKE FOR 3 HOURS MIN AT 375° TO 400°F. PART MUST BE PLATED AFTER DRILLING 0.055 (1.397) DIA HOLE.
14. REQUIREMENTS OF SOAP A0079194 APPLY.

NOTE: LARGER NUMBER IS IN MILLIMETERS; SMALLER NUMBER IS IN INCHES





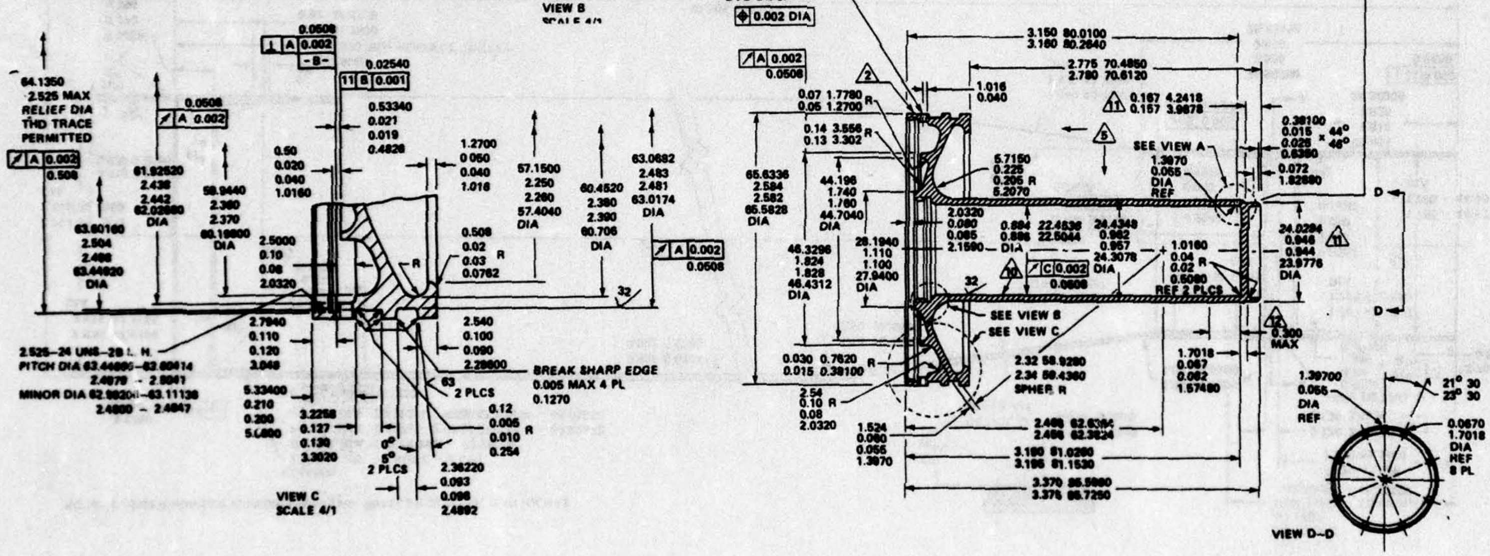
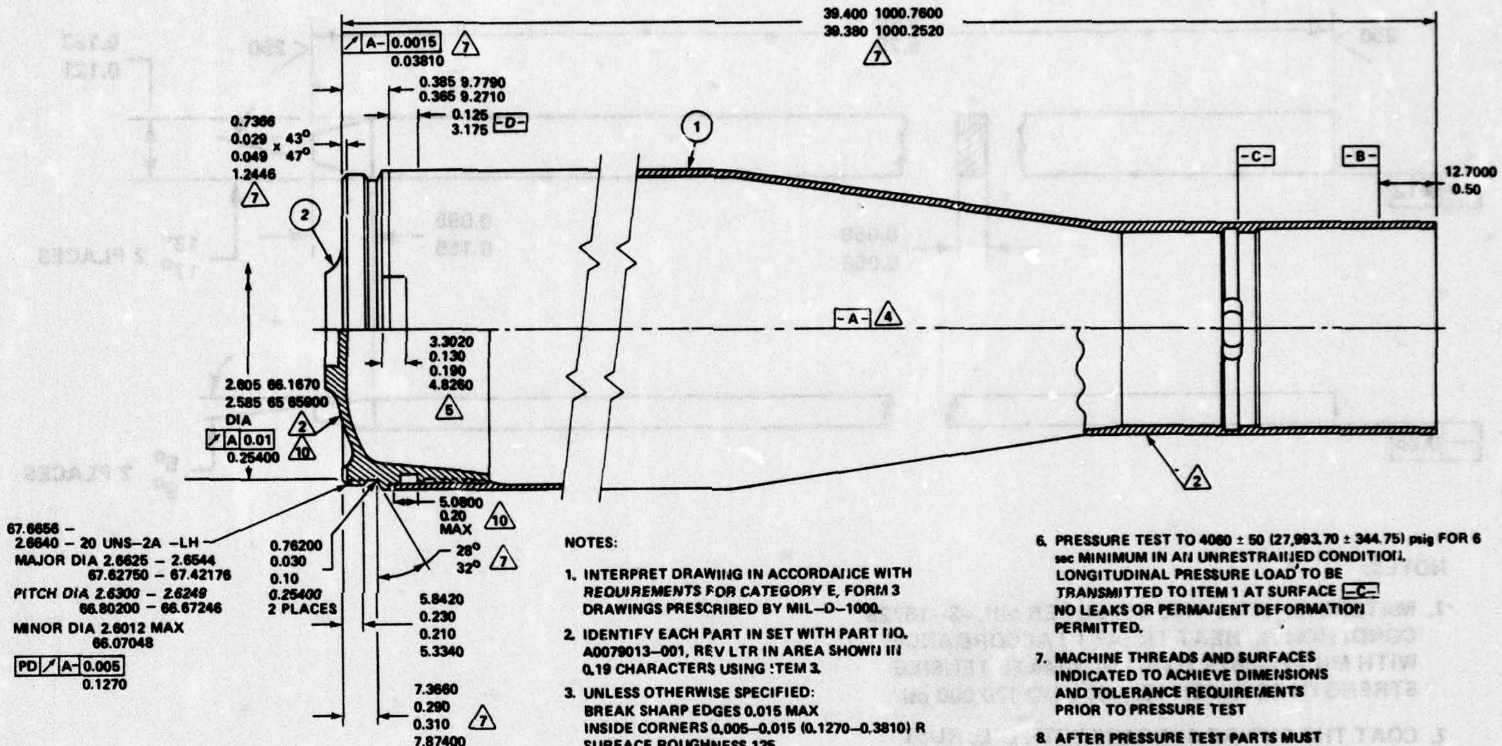


Figure 7. Flight forward closure.



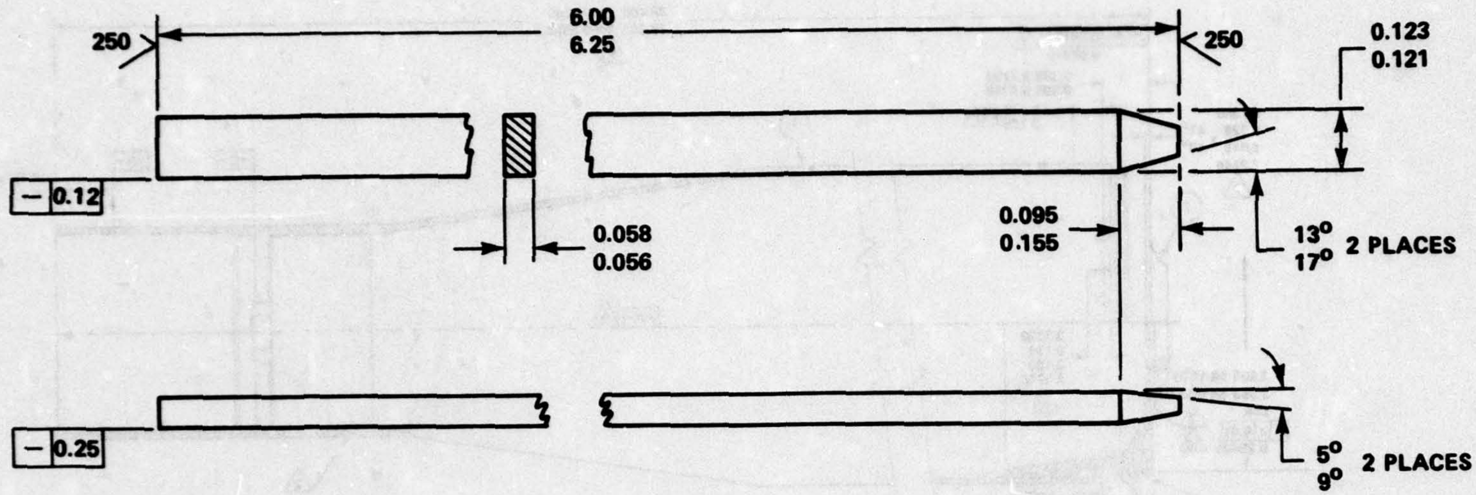
NOTE: LARGER NUMBER IS IN MILLIMETERS; SMALLER NUMBER IS IN INCHES

NOTES:

1. INTERPRET DRAWING IN ACCORDANCE WITH REQUIREMENTS FOR CATEGORY E, FORM 3 DRAWINGS PRESCRIBED BY MIL–D–1000.
2. IDENTIFY EACH PART IN SET WITH PART NO. A0079013–001, REV LTR IN AREA SHOWN IN 0.19 CHARACTERS USING ITEM 3.
3. UNLESS OTHERWISE SPECIFIED: BREAK SHARP EDGES 0.015 MAX INSIDE CORNERS 0.005–0.015 (0.1270–0.3810) R SURFACE ROUGHNESS 125
4. DATUM -A- IS DEFINED AS A LINE PASSING THROUGH THE CENTER OF THE OUTSIDE DIA AT DATUM -D- AND -B- (S).
5. TORQUE ITEM 1 AND ITEM 2 TO 45–55 ft lb SCRIBE LINE 0.005 (0.1270) MAX DEEP AS SHOWN. ANGULAR LOCATION OPTIONAL.
6. PRESSURE TEST TO 4060 ± 50 (27,993.70 ± 344.75) psig FOR 6 sec MINIMUM IN AN UNRESTRAINED CONDITION. LONGITUDINAL PRESSURE LOAD TO BE TRANSMITTED TO ITEM 1 AT SURFACE -C- NO LEAKS OR PERMANENT DEFORMATION PERMITTED.
7. MACHINE THREADS AND SURFACES INDICATED TO ACHIEVE DIMENSIONS AND TOLERANCE REQUIREMENTS PRIOR TO PRESSURE TEST
8. AFTER PRESSURE TEST PARTS MUST MEET DIMENSIONAL REQUIREMENTS OF DRAWINGS A0079011 AND A0079012.
9. ALL SURFACES TO BE PROTECTED WITH ITEM 4.
10. VIBRAETCH NONRECURRING SERIAL NO. OF BOTH PARTS IN AREA INDICATED.

Figure 8. Flight case closure set.

NOTE: LARGER NUMBER IS IN MILLIMETERS; SMALLER NUMBER IS IN INCHES



NOTES:

1. MATERIAL: A1S1 4130 STEEL PER MIL–S–18729 CONDITION N. HEAT TREAT IN ACCORDANCE WITH MIL–H–6875 TO AN ULTIMATE TENSILE STRENGTH BETWEEN 150,000 AND 170,000 psi.
2. COAT THE ENTIRE SURFACE WITH OIL, RUST PREVENTIVE PER MIL–L–3150.
3. MAGNETIC PARTICLE INSPECT PER MIL–I–6868. NO CRACKS PERMITTED.

Figure 9. Flight retaining Ortman key.

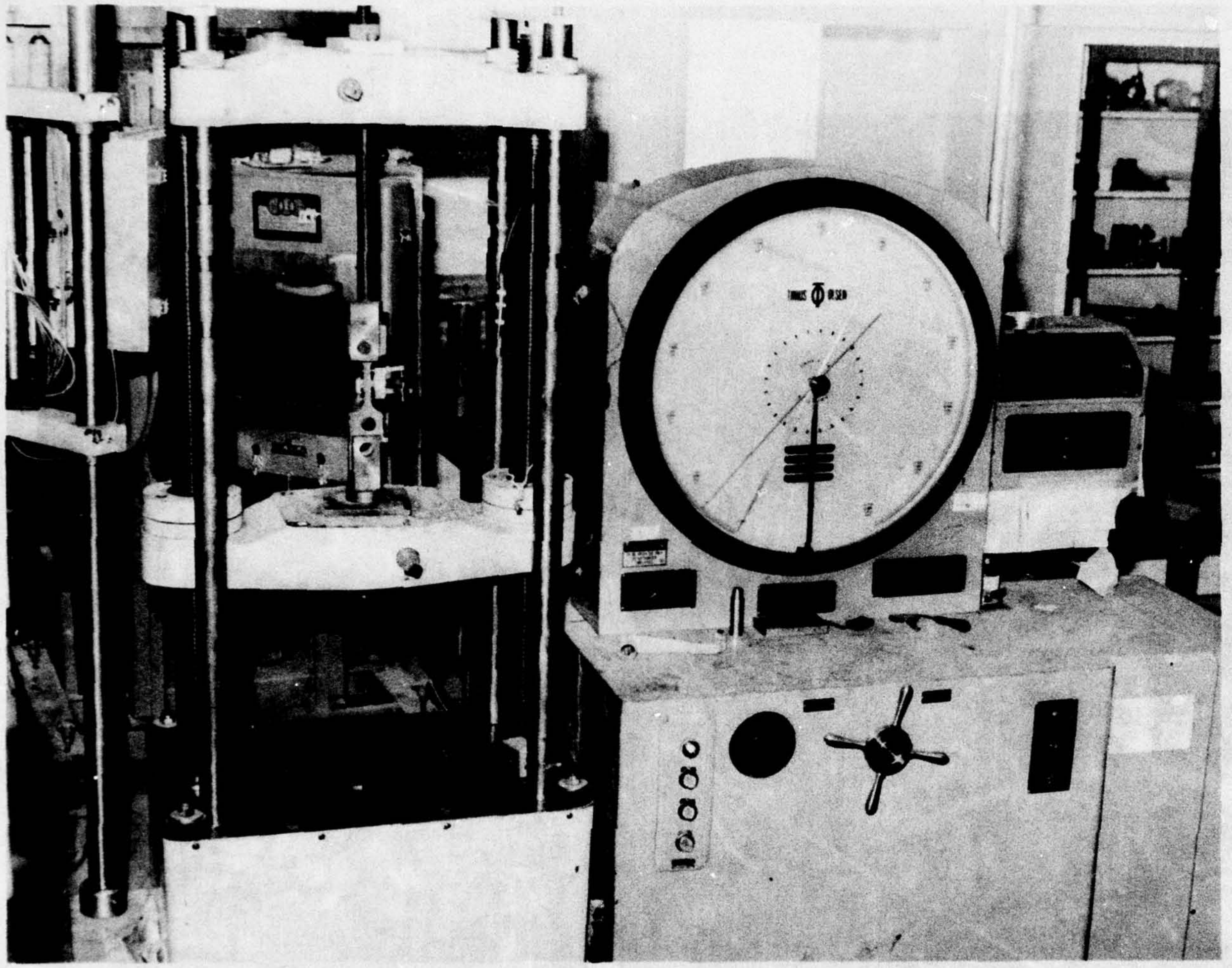


Figure 10. Tinius Olsen tensile machine.

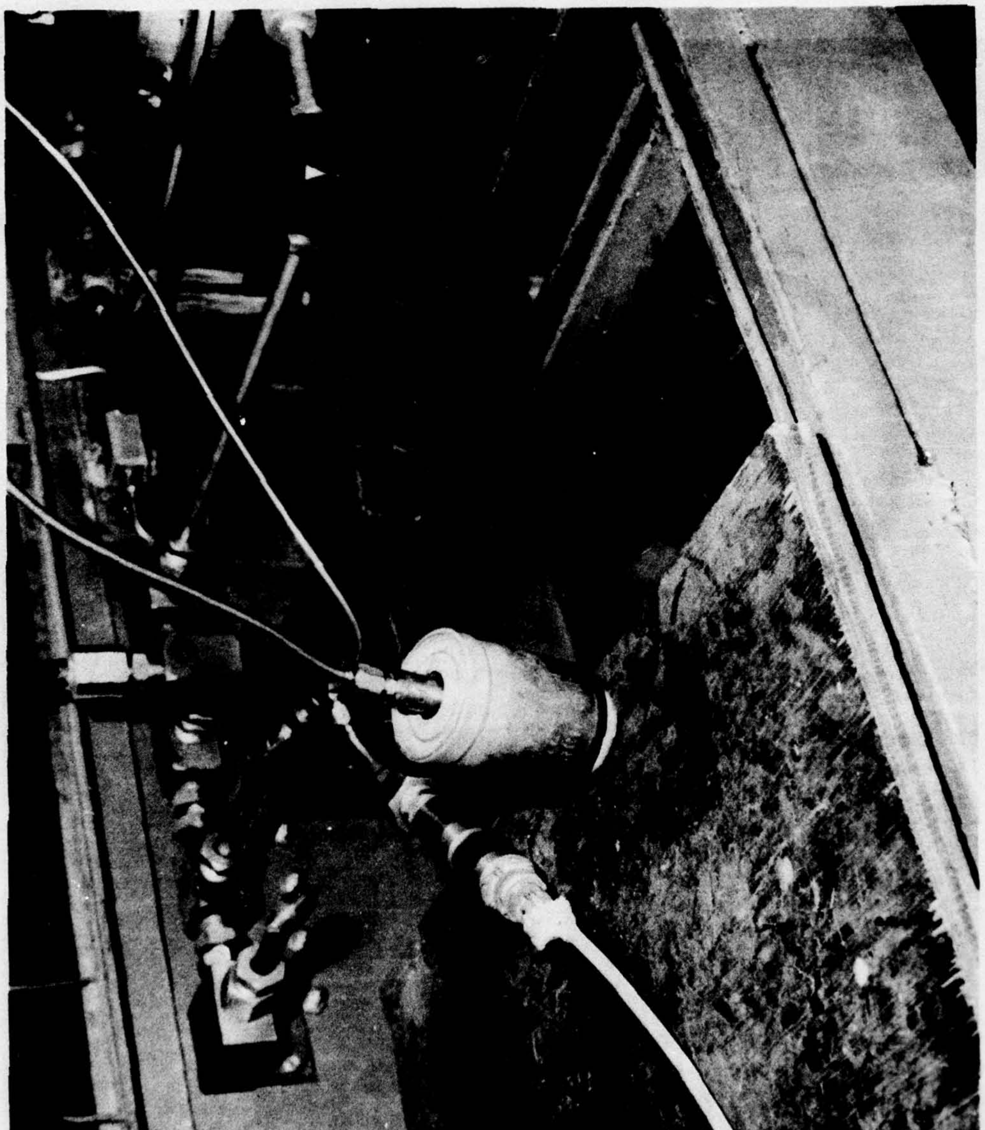


Figure 11. Hydrostatic test facility.

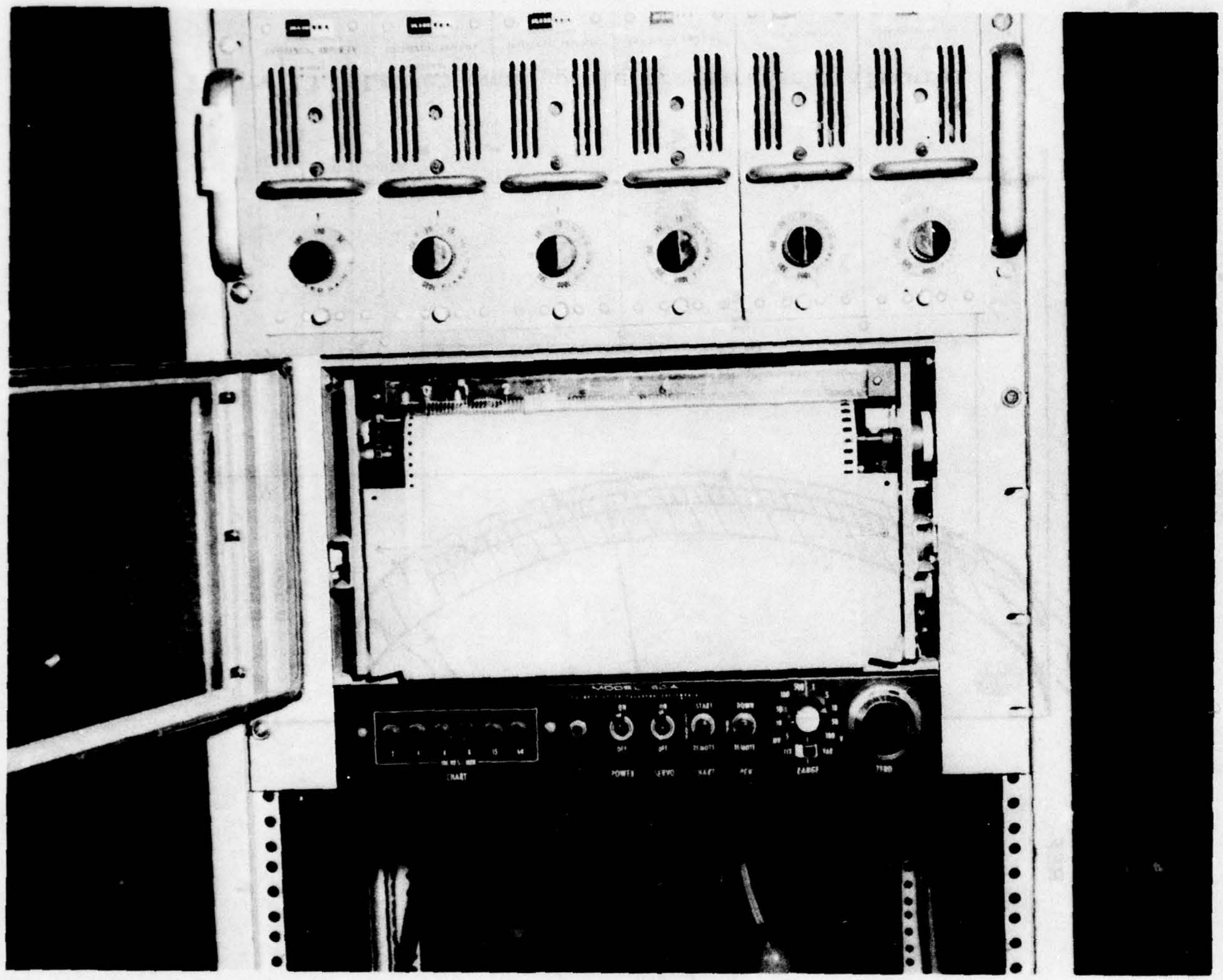


Figure 12. Mosely Model 80A recorder.

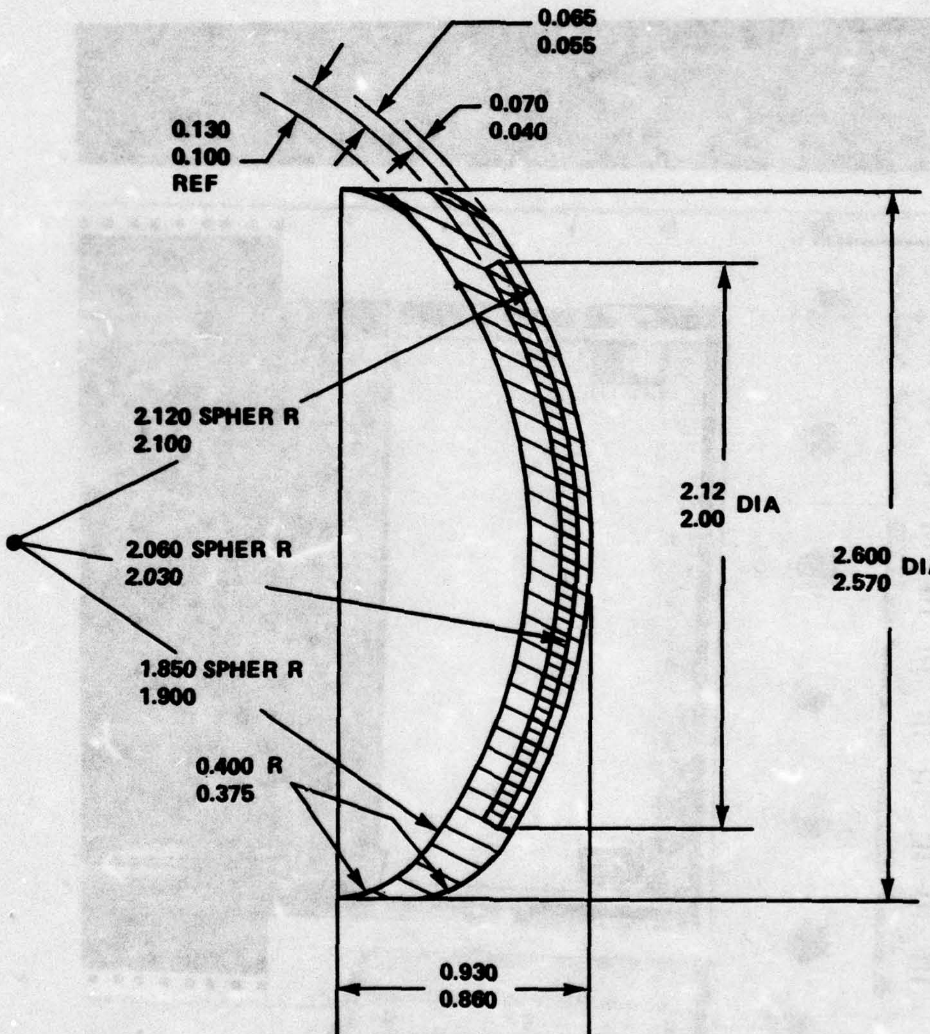


Figure 13. Launch case nozzle pressure seal fixture.

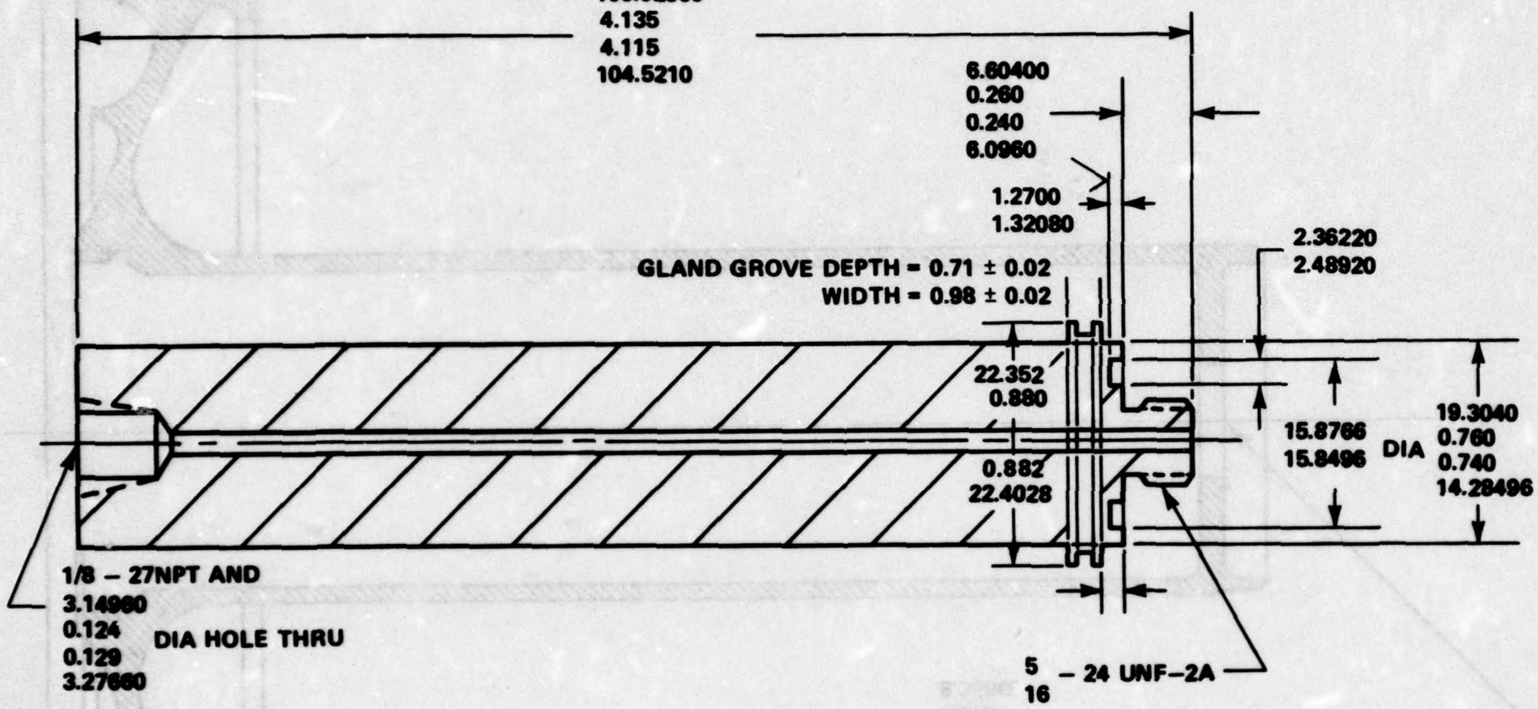


Figure 14. Pressure seal fixture for launch inner case.

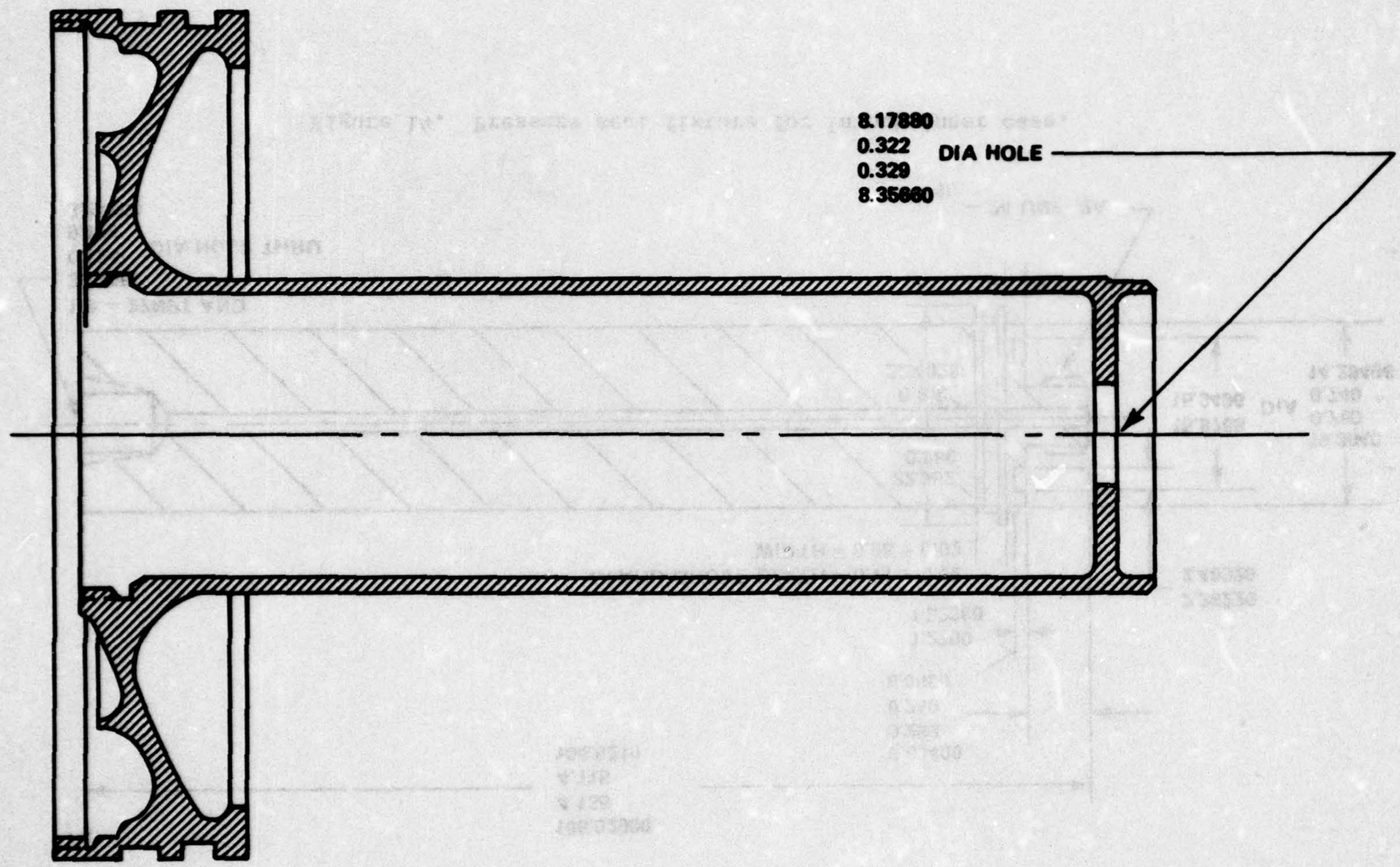


Figure 15. Modification of launch forward closure for hydroburst test.

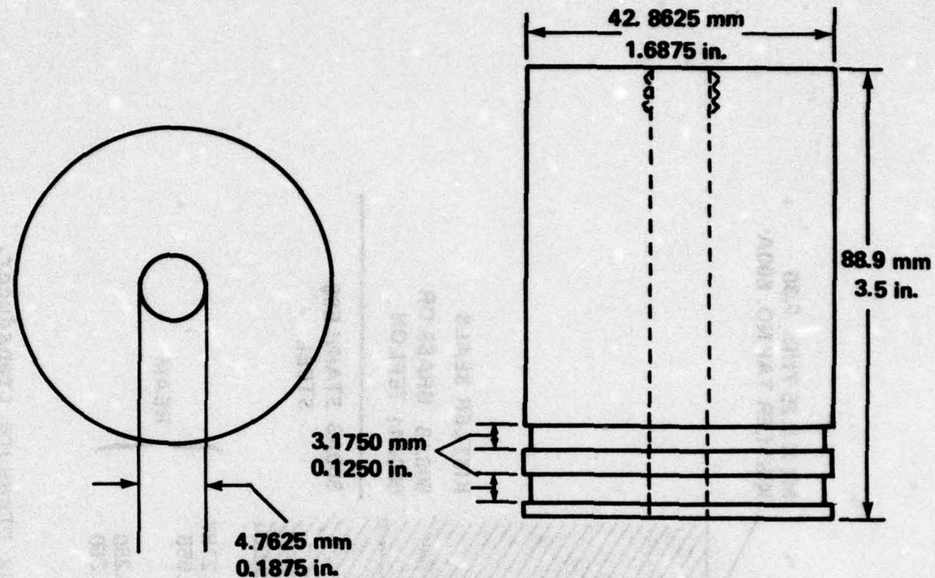


Figure 16. Flight case hydroburst fixture.

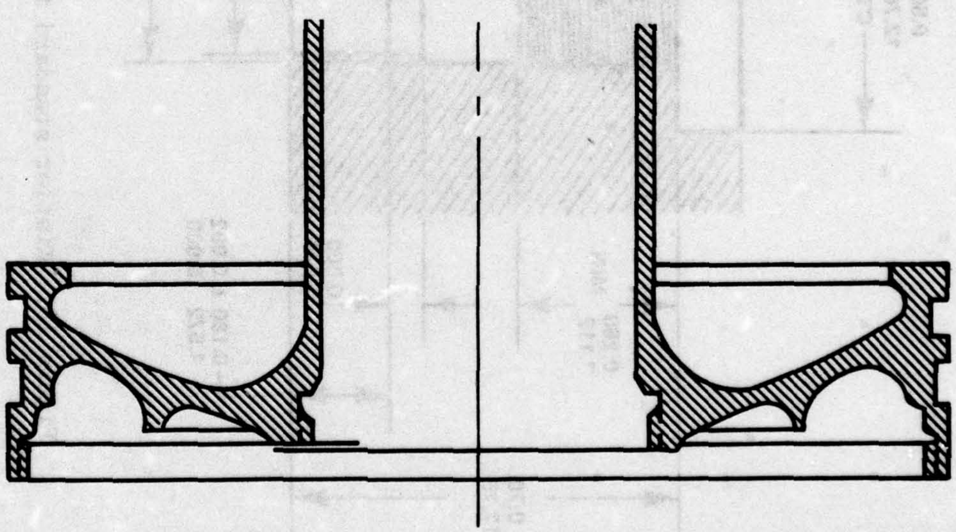


Figure 17. Modification of launch forward closure for dynamic burst test.

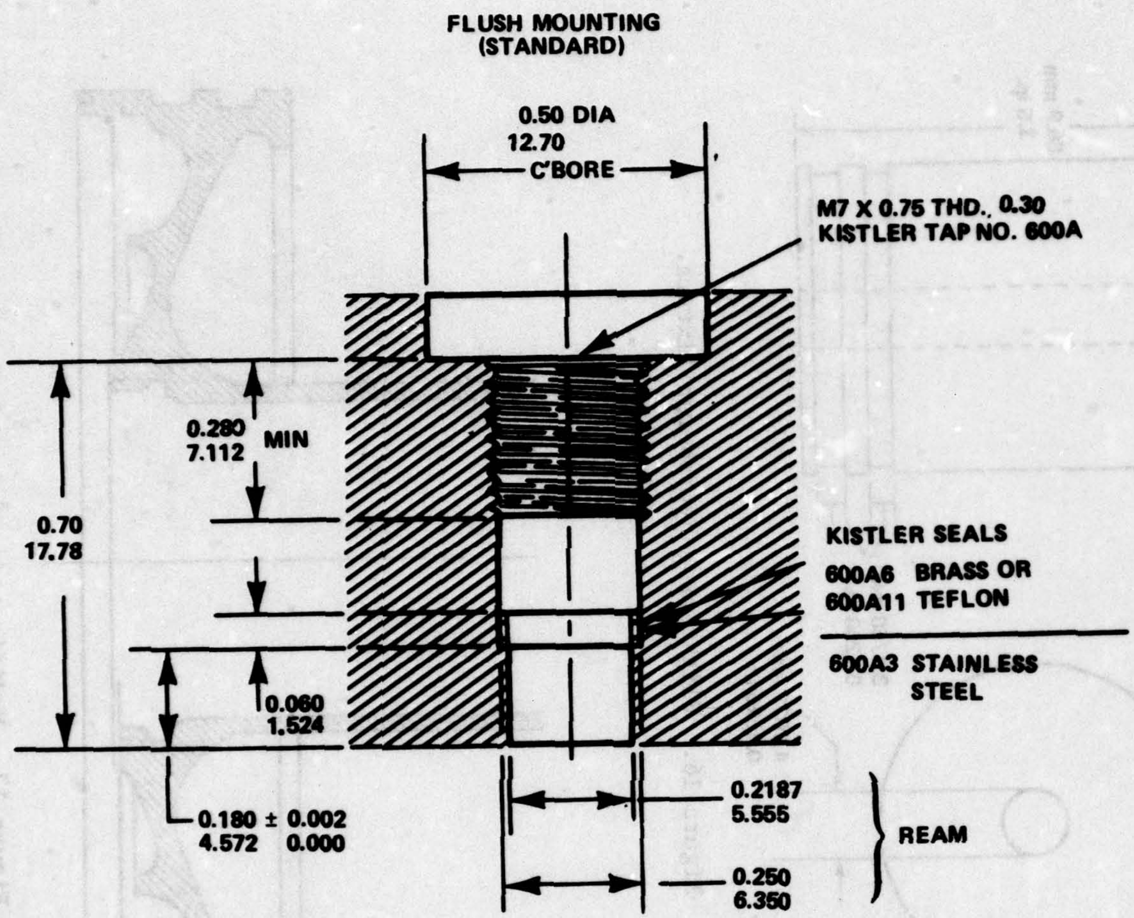


Figure 18. Kistler standard flush mounting pressure transducer.

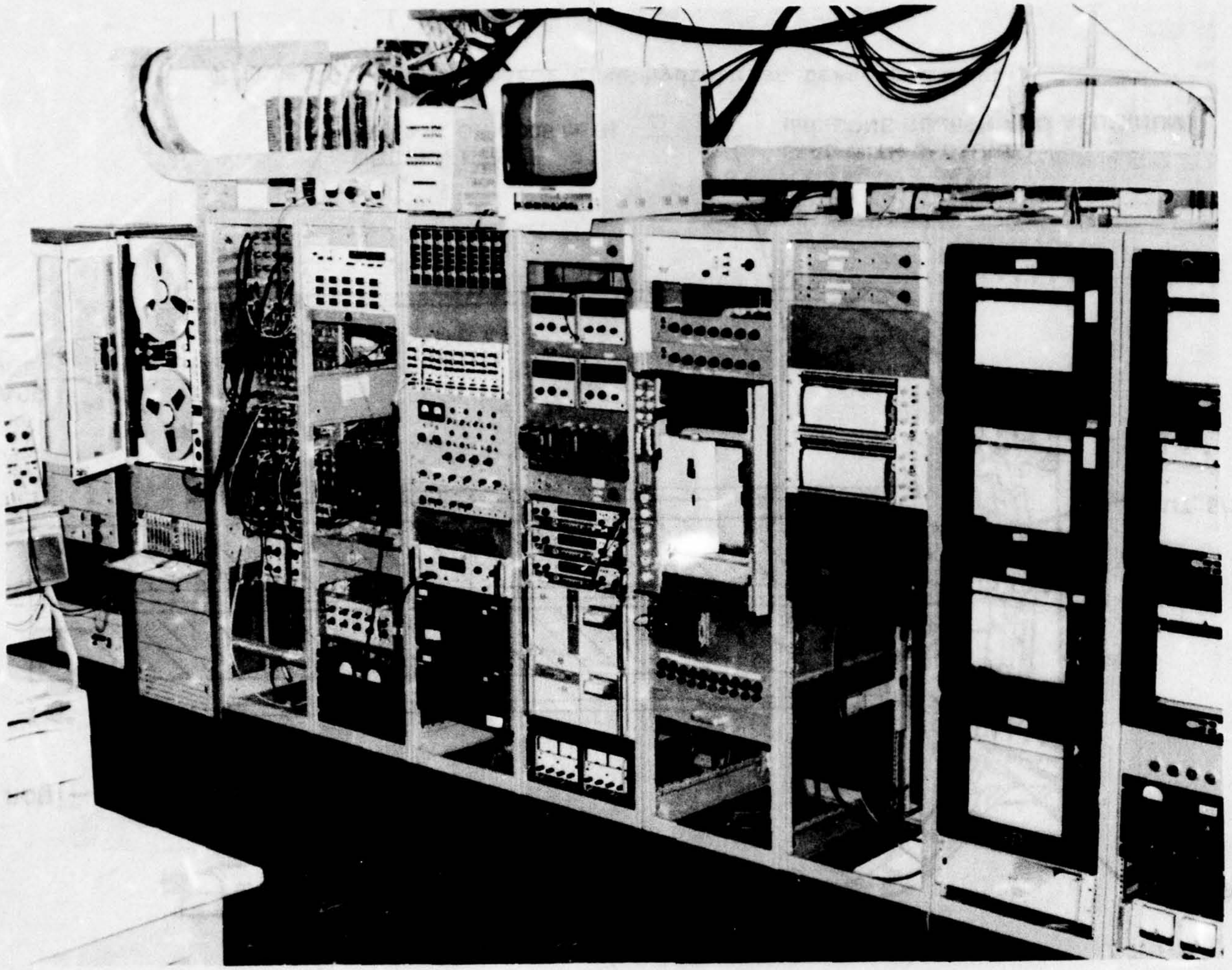


Figure 19. Bell and Howell 3700B magnetic analog recorder.

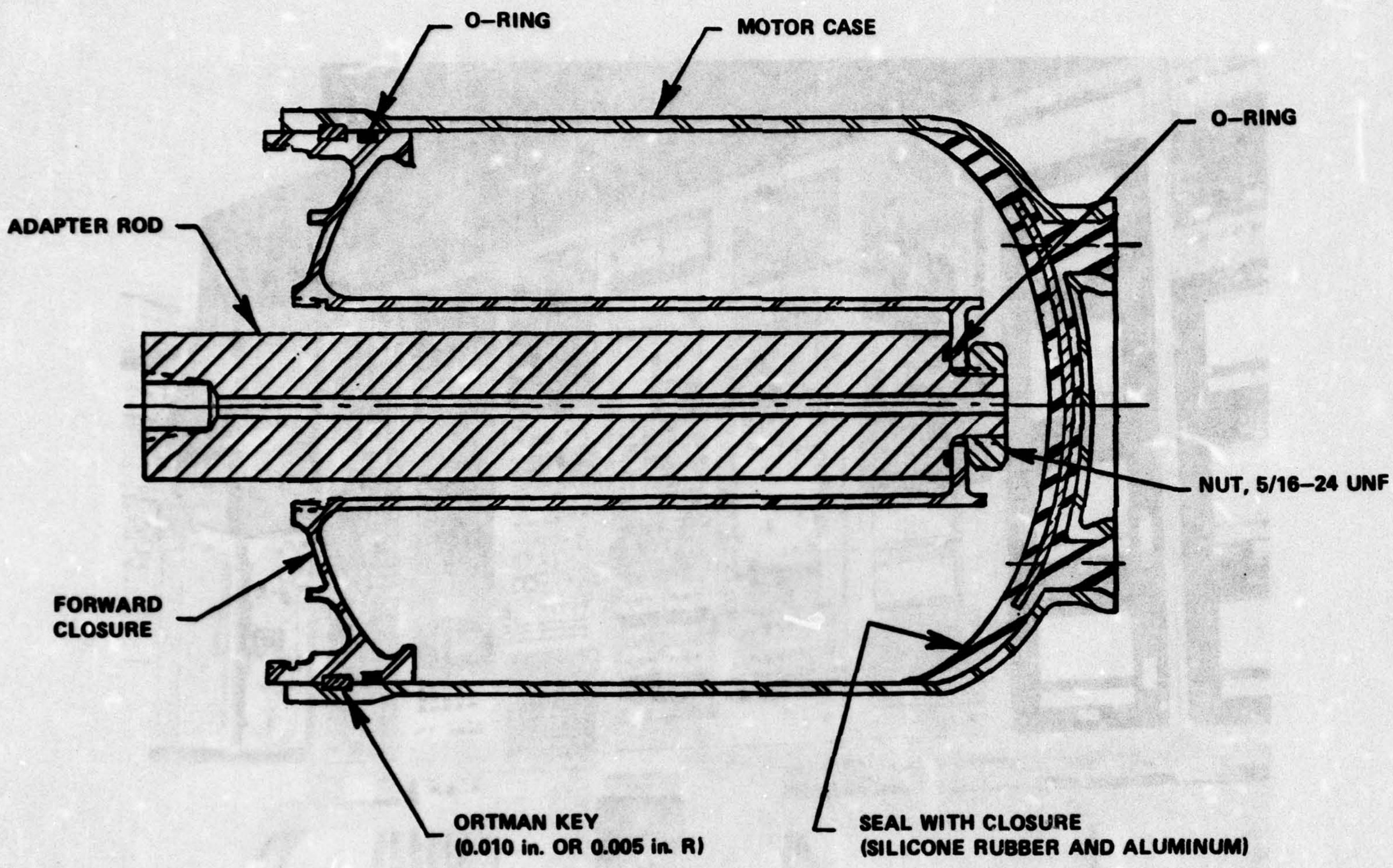


Figure 20. Launch motor case hydroburst test assembly.

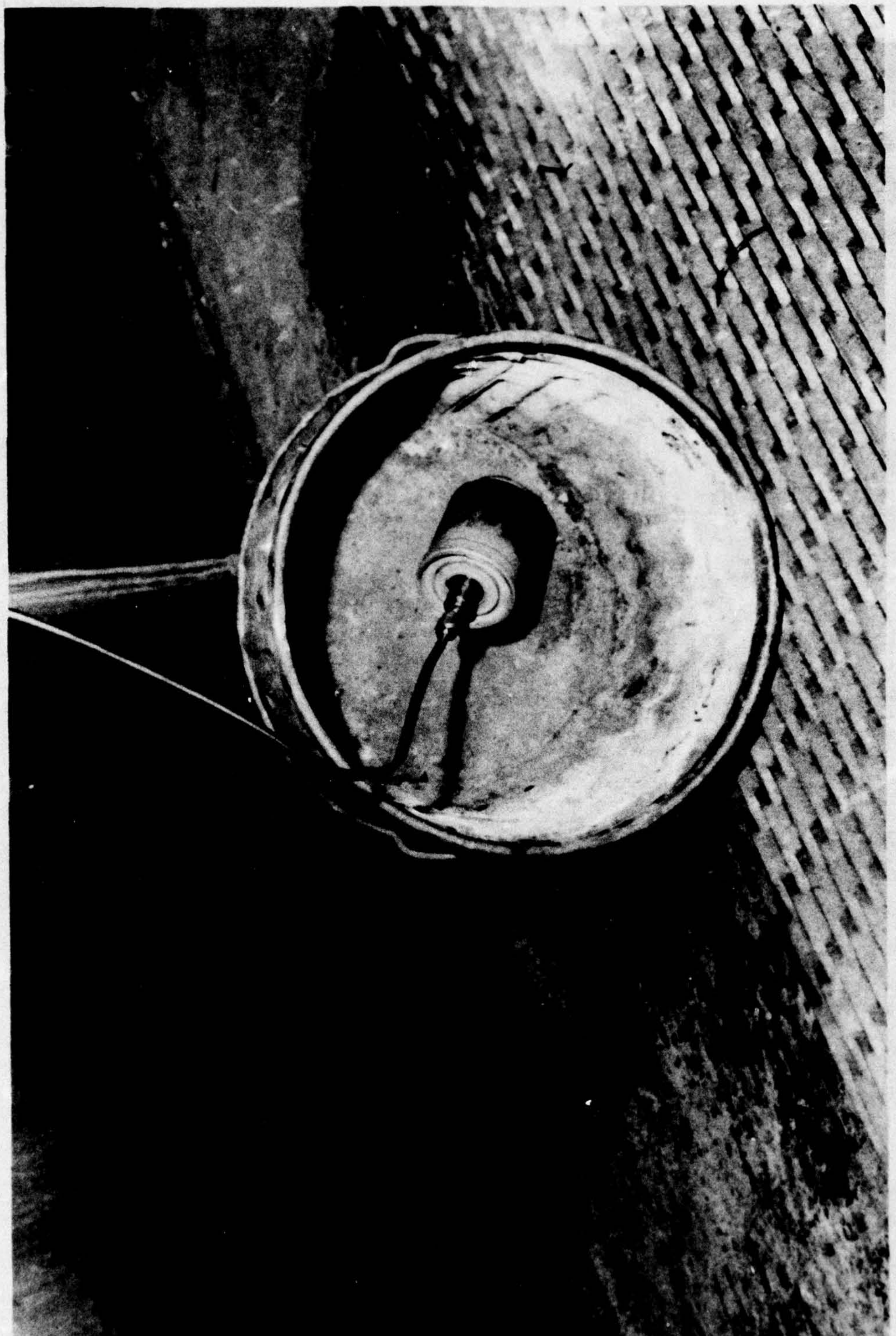


Figure 21. Launch motor case ready for hydroburst.

Figure 22. Launch motor case after hydroburst.

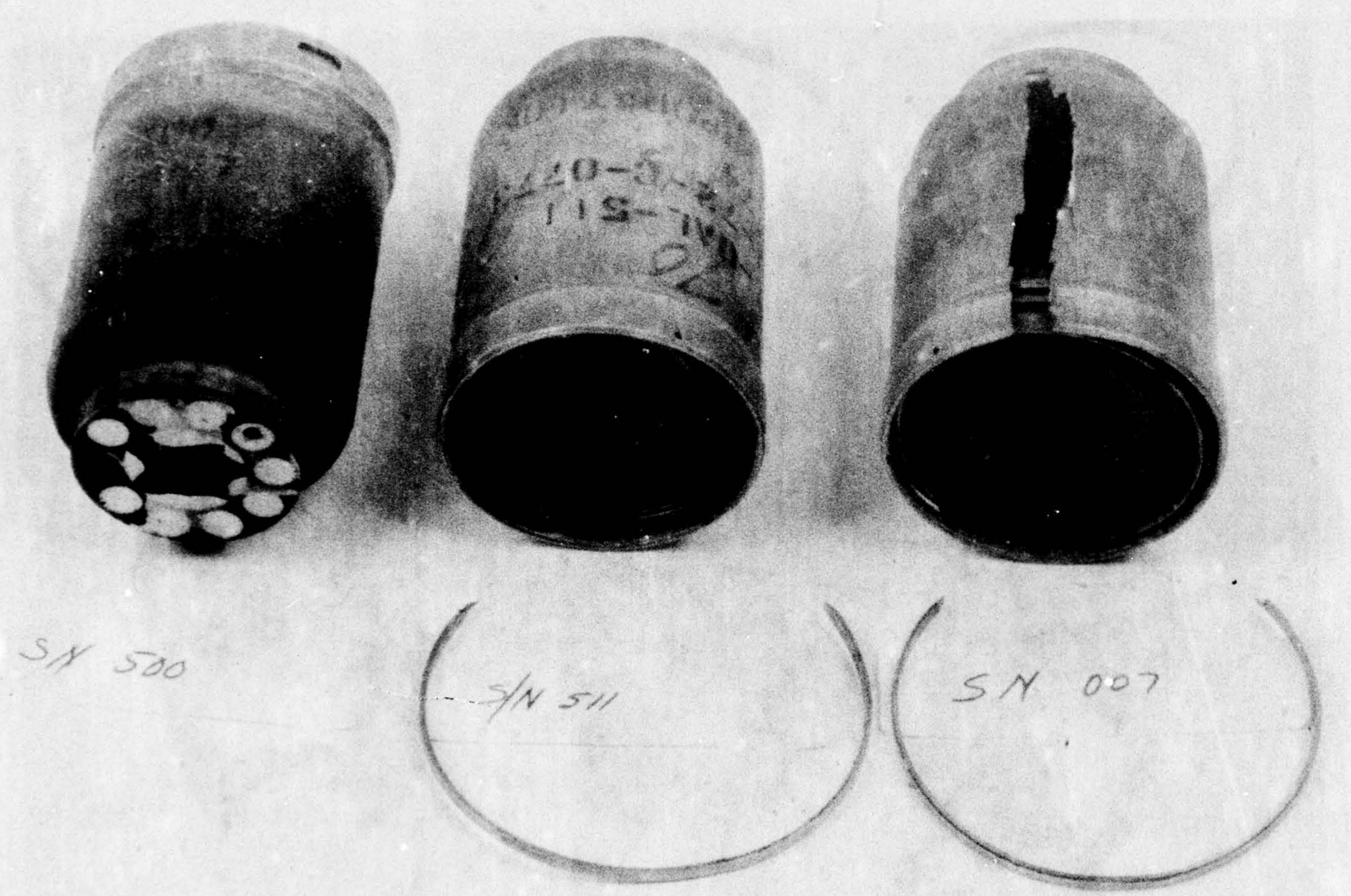


Figure 23. Launch motor cases (S/N 500, 511, and 007).

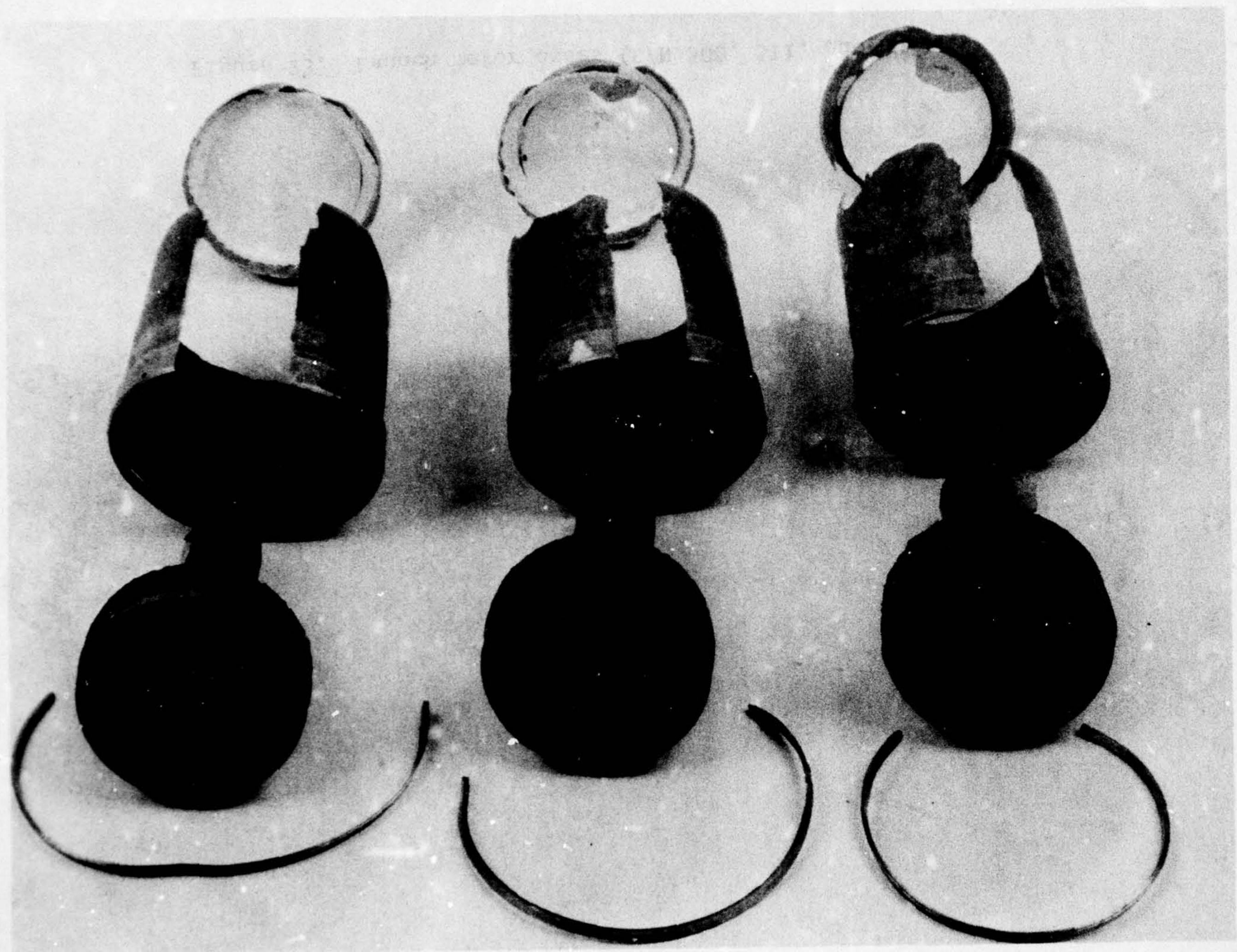


Figure 24. Launch motor cases (S/N 012, 011, and 013) after hydroburst.

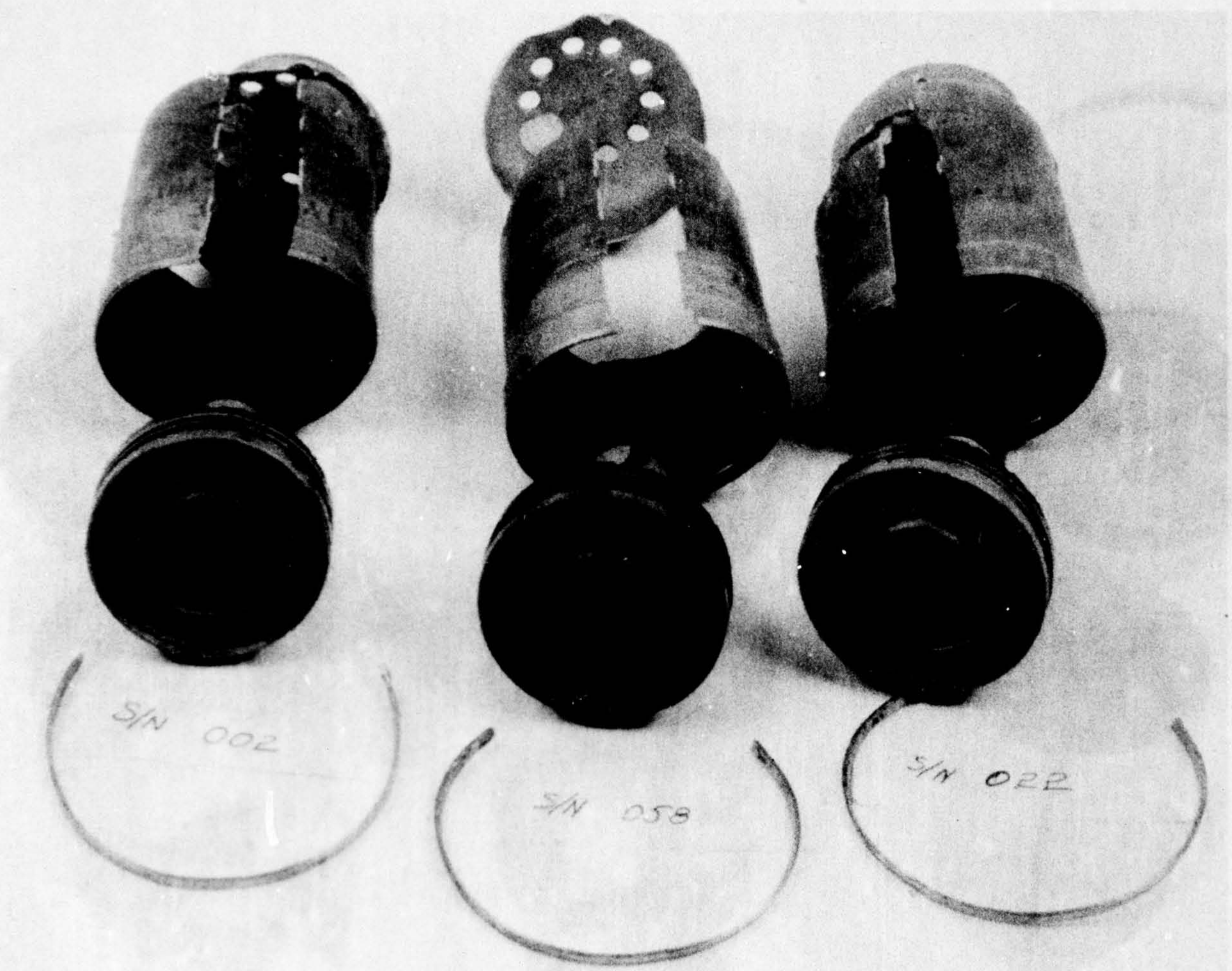


Figure 25. Launch motor cases (S/N 002, 058, and 022) after hydroburst.

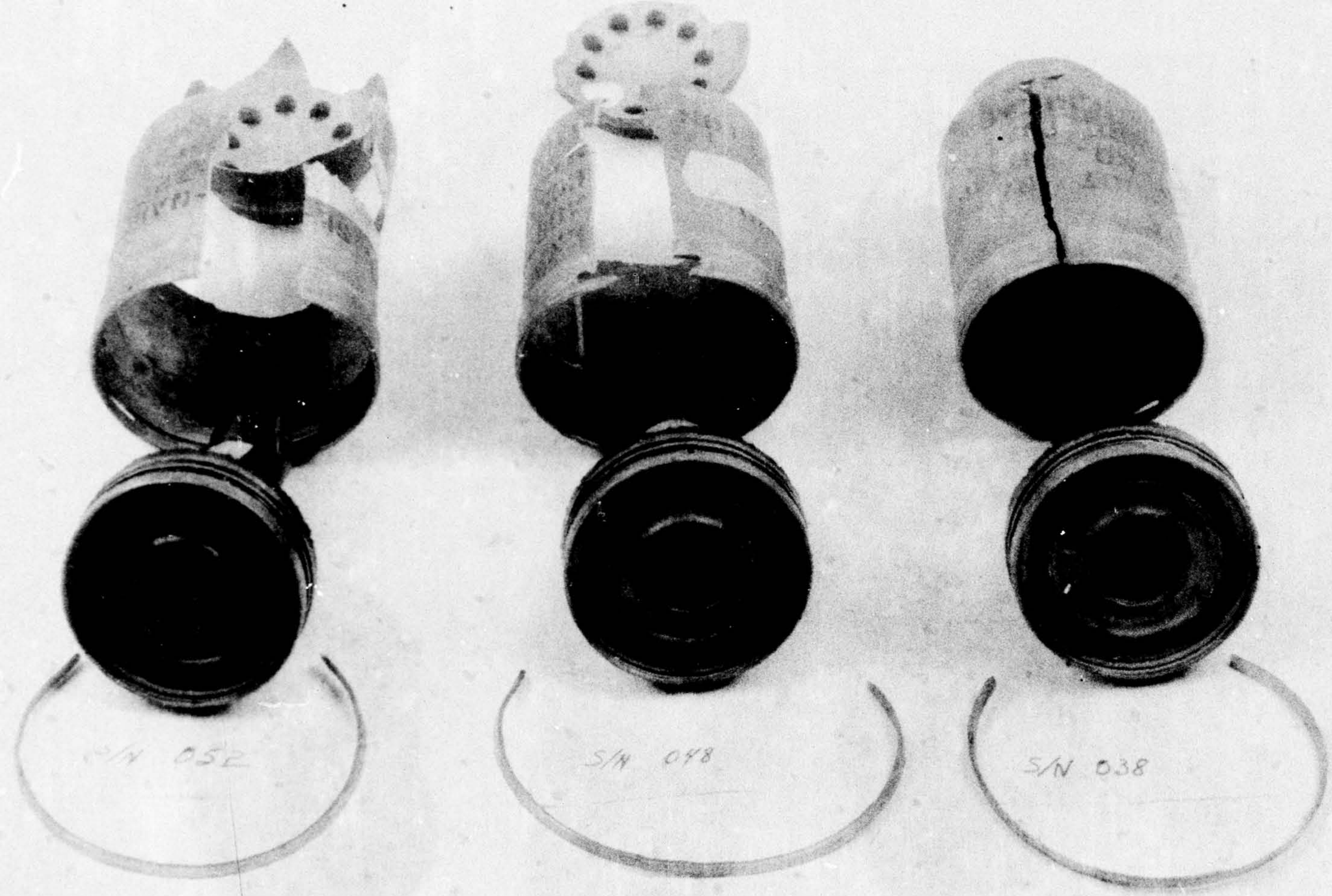


Figure 26. Launch motor cases (S/N 052, 048, and 038) after hydroburst.

Figure 27. Launch motor case (S/N 022) after dynamic burst.

Figure 28. Launch motor case (S/N 140) after dynamic burst.

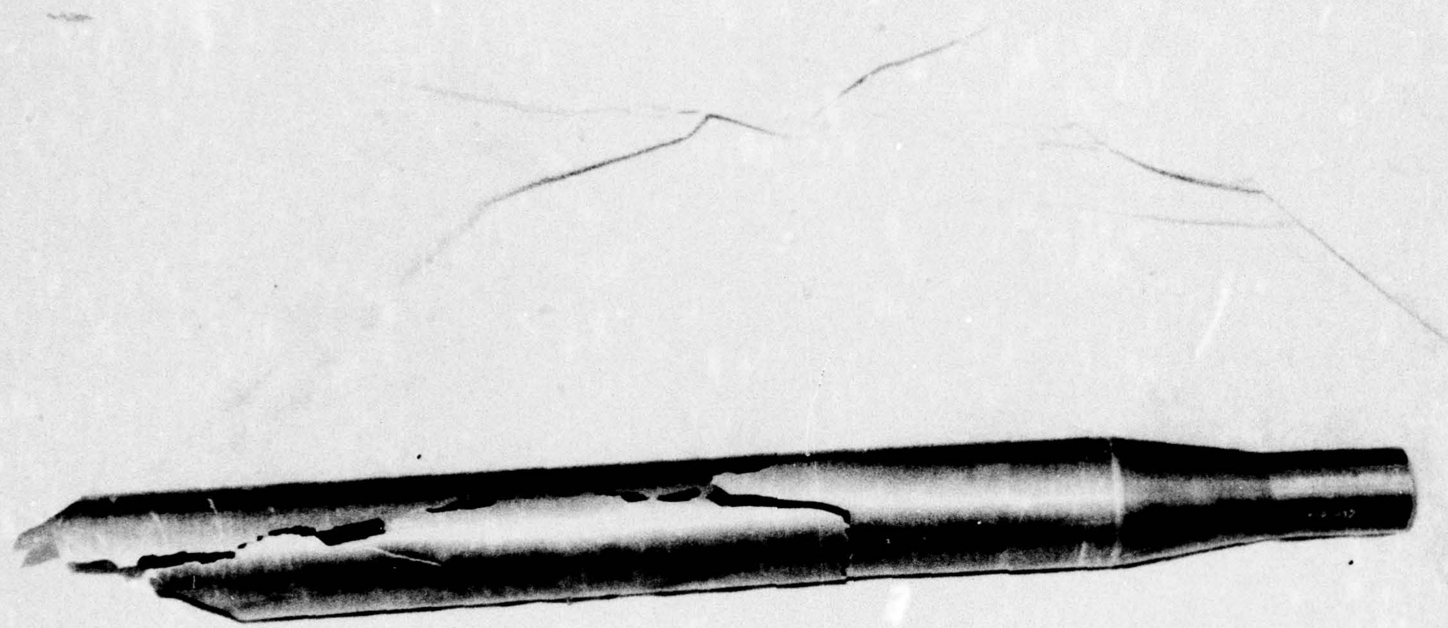


Figure 29. Marquardt flight case (S/N 294) after hydroburst.

Appendix A. COMPUTER PROGRAM LISTING FOR STATISTICAL HYPOTHESIS TESTING BETWEEN TWO MEANS

```
PROGRAM STA        74/74    OPT=1                                FTN 4.2+74355        09/27/75  11.02.06.        PAGE     1

      PROGRAM STA (INPUT,OUTPUT,TAPE5,TAPE6)
      DIMENSION  A(450), AVE(100),SUM(100),SUMSQ(100),SIGMA(100)
      DIMENSION        SLNX(450), SLNSSQ(450), ALLN(450)
      DIMENSION CLEV(3), FACTOR(3), I(100)
      COMMON // SLNX, SLNSSQ, ALLN
      DATA CLEV/0.10,0.05,0.001/
      DATA FACTOR/1.645,1.96,3.08/
      JJ=0
      DO 2 K=1,100
      IT=0
      SUM(I)=0
      SUMSQ(I)=0
    2 CONTINUE
      K=0
   11 CONTINUE
      CALL SORT (A, N)
      CALL STAT ( AVEI, SIGMAI, N, SUMI, SUMSQI, A)
      K=K+1
      JJ=JJ+1
      AVE(JJ)=AVEI
      SIGMA(JJ)=SIGMAI
      I(JJ)=N
      IT=IT+N
      SUM(K)= SUM(K)+SUMI
      SUMSQ(K)=SUMSQ(K)+SUMSQI
      READ(5,110) INDEX
  110 FORMAT(1X,I1)
      IF(INDEX.EQ.1)GO TO 11
   15 CONTINUE
      NJ=1
      KM1= K - 1
      DO 30 II=1,KM1
      IJK=II+1
      DO 20 L=IJK,K
       S=ABS(AVE(II)-AVE(L))
      T=SQRT(  (SIGMA(II)*SIGMA(II)/I(II))+(SIGMA(L)*SIGMA(L)/I(L)))
      ST=S/T
      WRITE (6,5212) ST
 5212 FORMAT(1X,F9.6)
      DO 21 M=1,3
      IF(ST-FACTOR(M).GT.0.0)GO TO 51
      WRITE( 6,5000) II, L   , CLEV(M)
 5000 FORMAT(2X,*THE DIFF. OF *I3 *AND *I3  *IS NOT SIGNIF ON THE *F9.5*
     1 LEVEL.*)
       GO TO 21
   51 WRITE(6,5001) II, L   , CLEV(M)
 5001 FORMAT(2X,*THE DIFF. OF *I3 *AND *I3  *IS SIGNIFICAN ON THE *F9.5*
     1 LEVEL *)
   21 CONTINUE
   20 CONTINUE
   30 CONTINUE
      STOP
      END
```

```
      SUBROUTINE SORT (A, N)
      DIMENSION E(50,9),A(450)
      WRITE (5,5113)
 5113 FORMAT(5H1INPUT)
      DO 45 I=1,50
      NN=I
      READ(5,100) (E(I,J),J=1,9)
  100 FORMAT (        9F8.2)
      WRITE (6,5111) (E(I,J),J=1,9)
 5111 FORMAT(1X,9F9.2)
      IF (E(I,1).EQ.0.0)  GO TO 46
   45 CONTINUE
      STOP "TOO MANY VALUES"
   46 CONTINUE
      K=0
      DO 20 I=1,NN
      DO 30 J=1,9
      K=K+1
      A(K)=E(I,J)
   30 CONTINUE
   20 CONTINUE
      M=NN*9
      DO 35  K=1,M
      NN=K
      IF (A(K).EQ.0.0) GO TO 36
   35 CONTINUE
   36 N=NN-1
      NM=N-1
      DO300 I=1,NM
      JM=N-I
      DO 200 J=1,JM
      JP1=J+1
      IF(A(J).LT.A(JP1))GO TO 200
      TEMP=A(J)
      A(J)=A(JP1)
      A(JP1)=TEMP
  200 CONTINUE
  300 CONTINUE
      RETURN
      END
```

```
      SUBROUTINE STAT(AVE,SIGMA,N,SUM,SUMSQ,A)
      COMMON // SLNX, SLNSSQ, ALLN
      DIMENSION A(1), SLNX(450), SLNSSQ(450), ALLN(450)
      SUM=0.0
      SUMSQ=0.0
      SLNXP=0.0
      SLNSQP=0.0
 5112 FORMAT(74H0   I        X         SUM X      SUM X**2   SUM LN(X) SUM(
     1LN(X))**2  WEIBULL,/,/)
      WRITE (6,5112)
      DO 30 J=1,N
      SUM=SUM+A(J)
      SUMSQ=SUMSQ+A(J)*A(J)
      SLNX(J)=SLNXP+ALOG(A(J))
      SLNXP=SLNX(J)
      SLNSSQ(J)=SLNSQP+ALOG(A(J))*ALOG(A(J))
      SLNSQP=SLNSSQ(J)
      ALLN(J)=ALOG(ALOG(FLOAT(N)/(FLOAT(N)+0.5-FLOAT(J))))
      WRITE (6,5211) J, A(J), SUM, SUMSQ, SLNX(J), SLNSSQ(J), ALLN(J)
 5211 FORMAT(1X,I4,1X,F8.1,,1X,F11.1,1X,F12.1,1X,F12.2,1X,F12.2,1X,F8.5)
   30 CONTINUE
      AVE=SUM/N
      SIGMA=SQRT(    (SUMSQ-AVE*AVE*N)/(N-1))
      WRITE (6,6113) AVE, SIGMA
 6113 FORMAT      (//,23H)     AVERAGE       SIGMA, /1X,F12.3,1X,F12.3)
      RETURN
      END
```

Appendix B. PRINTOUT OF STATISTICAL COMPARISON OF DYNAMIC BURST DATA TO HYDROBURST DATA

Dynamic Burst

1INPUT

5880.00	6000.00	6558.00	6640.00	6800.00	6391.00	6742.00	8778.00	8474.00
-0.00	-0.00	-0.00	-0.00	-0.00	-0.00	-0.00	-0.00	-0.00

0	I	X	SUM X	SUM X**2	SUM LN(X)	SUM(LN(X))**2	WEIBULL
	1	5880.0	5880.0	34574400.0	8.68	75.33	-2.86193
	2	6000.0	11880.0	70574400.0	17.38	151.01	-1.70198
	3	6391.0	18271.0	111419281.0	26.14	227.80	-1.12263
	4	6558.0	24829.0	154426645.0	34.93	305.03	-.70831
	5	6640.0	31469.0	198516245.0	43.73	382.49	-.36651
	6	6742.0	38211.0	243970809.0	52.55	460.21	-.05714
	7	6800.0	45011.0	290210809.0	61.37	538.09	.24759
	8	8474.0	53485.0	362019485.0	70.42	619.89	.58320
	9	8778.0	62263.0	439072769.0	79.50	702.34	1.06139

0	AVERAGE	SIGMA
	6918.111	1020.442

Hydroburst

1INPUT

4180.00	6570.00	7100.00	7700.00	7990.00	8100.00	7500.00	7900.00	7750.00
8150.00	7850.00	8350.00	7750.00	8100.00	8400.00	7800.00	7650.00	7800.00
-0.00	-0.00	-0.00	-0.00	-0.00	-0.00	-0.00	-0.00	-0.00

0 I	X	SUM X	SUM X**2	SUM LN(X)	SUM(LN(X))**2	WEIBULL
1	4180.0	4180.0	17472400.0	8.34	69.52	-3.56947
2	6570.0	10750.0	60637300.0	17.13	146.79	-2.44172
3	7100.0	17850.0	111047300.0	26.00	225.43	-1.90025
4	7500.0	25350.0	167297300.0	34.92	305.04	-1.53144
5	7650.0	33000.0	225819800.0	43.86	385.01	-1.24590
6	7700.0	40700.0	285109800.0	52.81	465.10	-1.00884
7	7750.0	48450.0	345172300.0	61.77	545.30	-.80291
8	7750.0	56200.0	405234800.0	70.72	625.50	-.61805
9	7800.0	64000.0	466074800.0	79.68	705.81	-.44773
10	7800.0	71800.0	526914800.0	88.64	786.13	-.28727
11	7850.0	79650.0	588537300.0	97.61	866.56	-.13300
12	7900.0	87550.0	650947300.0	106.59	947.10	.01840
13	7990.0	95540.0	714787400.0	115.57	1027.85	.17027
14	8100.0	103640.0	780397400.0	124.57	1108.84	.32663
15	8100.0	111740.0	846007400.0	133.57	1189.83	.49324
16	8150.0	119890.0	912429900.0	142.58	1270.94	.68010
17	8350.0	128240.0	982152400.0	151.61	1352.48	.91024
18	8400.0	136640.0	1052712400.0	160.64	1434.13	1.27635

0	AVERAGE	SIGMA
	7591.111	953.723

1.650656

THE DIFF. OF 1AND 2IS SIGNIFICAN ON THE .10000 LEVEL

THE DIFF. OF 1AND 2IS NOT SIGNIF ON THE .05000 LEVEL.

THE DIFF. OF 1AND 2IS NOT SIGNIF ON THE .00100 LEVEL.

Appendix C. PRINTOUT OF STATISTICAL COMPARISON OF VARIOUS COMBINATIONS OF DIFFERENT TYPES OF BURST AND ORTMAN KEY DATA.

Dynamic Burst, 0.127-mm (0.005-in.) key.

```
1INPUT
   8778.00   8474.00     -0.00     -0.00     -0.00     -0.00     -0.00     -0.00    -0.00
     -0.00     -0.00     -0.00     -0.00     -0.00     -0.00     -0.00     -0.00    -0.00
0  I        X         SUM X     SUM X**2   SUM LN(X) SUM(LN(X))**2  WEIBUL.

   1   8474.0      8474.0   71808676.0        9.04         81.81  -1.24590
   2   8778.0     17252.0  148861960.0       18.12        164.25    .32663

0  AVERAGE       SIGMA
   8626.000      214.960
```

Dynamic Burst, 0.254-mm (0.010-in.) key.

```
1INPUT
   5880.00   6000.00   6558.00   6640.00   6800.00   6391.00   6742.00     -0.00    -0.00
     -0.00     -0.00     -0.00     -0.00     -0.00     -0.00     -0.00     -0.00    -0.00
0  I        X         SUM X     SUM X**2   SUM LN(X) SUM(LN(X))**2  WEIBUL.

   1   5880.0      5880.0   34574400.0        8.68         75.33  -2.60223
   2   6000.0     11880.0   70574400.0       17.38        151.01  -1.42229
   3   6391.0     18271.0  111419281.0       26.14        227.80   -.81682
   4   6558.0     24829.0  154426645.0       34.93        305.03   -.36651
   5   6640.0     31469.0  198516245.0       43.73        382.49    .02919
   6   6742.0     38211.0  243970809.0       52.55        460.21    .43207
   7   6800.0     45011.0  290210809.0       61.37        538.09    .97042

0  AVERAGE       SIGMA
   6430.143      361.397
```

Hydroburst, 0.127-mm (0.005-in.) key.

1INPUT

7100.00	7650.00	7800.00	7700.00	7990.00	8100.00	7500.00	7900.00	7750.00
8150.00	7850.00	8350.00	7750.00	8100.00	8400.00	7800.00	-0.00	-0.00
-0.00	-0.00	-0.00	-0.00	-0.00	-0.00	-0.00	-0.00	-0.00

0 I	X	SUM X	SUM X**2	SUM LN(X)	SUM(LN(X))**2	WEIBUL.
1	7100.0	7100.0	50410000.0	8.87	78.64	-3.44990
2	7500.0	14600.0	106660000.0	17.79	158.25	-2.31831
3	7650.0	22250.0	165182500.0	26.73	238.22	-1.77255
4	7700.0	29950.0	224472500.0	35.68	318.30	-1.39893
5	7750.0	37700.0	284535000.0	44.64	398.50	-1.10793
6	7750.0	45450.0	344597500.0	53.59	478.70	-.86462
7	7800.0	53250.0	405437500.0	62.55	559.02	-.65144
8	7800.0	61050.0	466277500.0	71.52	639.34	-.45804
9	7850.0	68900.0	527900000.0	80.48	719.76	-.27743
10	7900.0	76800.0	590310000.0	89.46	800.31	-.10443
11	7990.0	84790.0	654150100.0	98.45	881.05	.06564
12	8100.0	92890.0	719760100.0	107.45	962.05	.23784
13	8100.0	100990.0	785370100.0	116.44	1043.04	.41860
14	8150.0	109140.0	851792600.0	125.45	1124.15	.61853
15	8350.0	117490.0	921515100.0	134.48	1205.69	.86163
16	8400.0	125890.0	992075100.0	143.52	1287.34	1.24292

0	AVERAGE	SIGMA
	7868.125	322.164

Hydroburst, 0.25-mm (0.010-in.) key.

```
1INPUT
    4180.00   6570.00      -0.00      -0.00      -0.00      -0.00      -0.00      -0.00      -0.00
     -0.00     -0.00      -0.00      -0.00      -0.00      -0.00      -0.00      -0.00      -0.00
0   I         X          SUM X      SUM X**2    SUM LN(X)  SUM(LN(X))**2  WEIBUL.

    1    4180.0       4180.0    17472400.0         8.34         69.52 -1.24591
    2    6570.0      10750.0    60637300.0        17.13        146.79   .32663
0     AVERAGE        SIGMA
      5375.000       1689.985
  10.745134
   THE DIFF. OF     1AND    2IS SIGNIFICAN ON THE      .10000 LEVEL
   THE DIFF. OF     1AND    2IS SIGNIFICAN ON THE      .05000 LEVEL
   THE DIFF. OF     1AND    2IS SIGNIFICAN ON THE      .00100 LEVEL
   4.405740
   THE DIFF. OF     1AND    3IS SIGNIFICAN ON THE      .10000 LEVEL
   THE DIFF. OF     1AND    3IS SIGNIFICAN ON THE      .05000 LEVEL
   THE DIFF. OF     1AND    3IS SIGNIFICAN ON THE      .00100 LEVEL
   2.698758
   THE DIFF. OF     1AND    4IS SIGNIFICAN ON THE      .10000 LEVEL
   THE DIFF. OF     1AND    4IS SIGNIFICAN ON THE      .05000 LEVEL
   THE DIFF. OF     1AND    4IS NOT SIGNIF ON THE      .00100 LEVEL.
   9.668309
   THE DIFF. OF     2AND    3IS SIGNIFICAN ON THE      .10000 LEVEL
   THE DIFF. OF     2AND    3IS SIGNIFICAN ON THE      .05000 LEVEL
   THE DIFF. OF     2AND    3IS SIGNIFICAN ON THE      .00100 LEVEL
    .877252
   THE DIFF. OF     2AND    4IS NOT SIGNIF ON THE      .10000 LEVEL.
   THE DIFF. OF     2AND    4IS NOT SIGNIF ON THE      .05000 LEVEL.
   THE DIFF. OF     2AND    4IS NOT SIGNIF ON THE      .00100 LEVEL.
   2.081575
   THE DIFF. OF     3AND    4IS SIGNIFICAN ON THE      .10000 LEVEL
   THE DIFF. OF     3AND    4IS SIGNIFICAN ON THE      .05000 LEVEL
   THE DIFF. OF     3AND    4IS NOT SIGNIF ON THE      .00100 LEVEL.
```

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